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PREDICTION OF SCHEDULED AND PREVENTATIVE MAINTENANCE WORKLOAD

Harris Government Information Systems

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This report documents the development of new techniques to predict Preventive Maintenance task completion times in relation to system and equipment design characteristics. Data derived from numerous expert maintainers via interviews and a subjective maintenance time estimation process were analyzed. The analysis led to the development of techniques for predicting preventive maintenance down time early in the design process. Two prediction products were developed, one to be used by maintainability engineers during system/equipment validation phase design and one to be used during full scale development phase design. Use of these products was discussed in the context of MIL-HDBK-472 procedures and as a means of reducing system maintenance costs. Keywords:

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SUMMARY

The prediction of preventive/scheduled maintenance down time has been a problem for design and maintenance engineers. Without a viable technique for prediction, design visibility isn't possible during development and design planning. Such visibility is necessary to provide the lowest possible life cycle maintenance costs.

This report provides two techniques from which scheduled/preventative down times can be predicted based on equipment design features and the amount of information available at the time.

The first prediction method was designed to use the limited amount of information that is available during the Validation phase of development. This technique uses generalized weighted reference tables which the engineer must fill out according to the <u>general</u> characteristics of the design. These weighted values are averaged and applied to a standard time line distribution which allows predictions/estimates of preventative/scheduled maintenance time to be made.

The second prediction method was designed to use the <u>specific</u> detailed information that is available during the Full Scale Development phase. The technique uses lists of individual task element times differentiated by design features, a mathematical model and expert judgement to fill any gaps in the task element list.

In comparing the two methods, it should be noted that the first method takes into consideration the administrative time necessary for a given maintenance task as well as the required active time, whereas, the second method calculates only the active time required to perform a specific task.

PREFACE

This study was conducted under Contract F30602-83-C-0066 with Rome Air Development Center, Griffiss AFB, New York. The RADC Program Manager was Lt. Lorraine Gozzo. The Principal Investigator was Mr. R. Jay Ritchie, Harris Government Information Systems Division.

The contributors to this report, listed in alphabetical order, include: James N. Irvin, John B. Mocharnuk, Jerome C. Notestine, R. Jay Ritchie, John C. Schmitt, and C. Peter Vaziri. The contributors wish to express their appreciation for the cooperation and suggestions from Mr. Jerry Klion from RADC, and from Mr. Craig Guy, Mr. Charles McElwee, Mr. William Russell, Mr. Bruce Pike, Mr. Joe Bryant from Harris GISD, and personnel from the Harris Cal Lab. Special thanks are due to Ms. Sally Senecal and Ms. Angela Fain for their assistance in composing this report and to Air Force Maintenence personnel at Patrick, Offutt, and MacDill Air Force Bases.

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1.0 INTRODUCTION

1.1 Statement of The Problem

This study was conducted in response to an emerging concern throughout the DoD regarding expenditures of time and money as well as expectations of large outyear manpower requirements which result from preventive maintenance. Recent estimates[1,2] indicate that between one-fourth and one-third of the total DoD budget is spent on maintenance and as much as two-thirds of total maintenance manhours fall into the category of preventive maintenance. Historically, no adequate or reliable method has existed for predicting the time or manhours required to keep electronic systems or equipments operational. Because no reliable prediction method has been available, the impact of scheduled and preventive maintenance on overall system maintenance requirements has rarely been included as part of system specifications or taken into account in maintainability design. Scheduled and preventive maintenance impacts manhour expenditures, system availability, and spares provisioning. For purposes of this effort, scheduled or preventive maintenance is defined as maintenance actions or tasks which are not associated with equipment failures per se, but are required to maintain system performance requirements. Examples of such actions or tasks include scheduled replacement of parts, realignment, adjustment, performance checks, calibration or cleaning.

Under the most commonly used design approaches, little emphasis is placed on preventive or scheduled maintenance during the design phases. As a result, once deployed, a system is often maintained as needed and a preventive

ıtenance philosophy is developed after the fact. This method is not icient, results in unanticipated downtime and manpower expenditures, and / times necessitates costly design modifications.

With virtually every electronic system and equipment requiring certain lacement of parts, realignment, adjustment, or other planned maintenance ion, a reliable method is warranted which will aid a designer or ntainability engineer in controlling and predicting the impact preventive ntenance will have on overall maintenance workload and time.

In response to this need, the present study has provided a reliable and id method for predicting scheduled/preventive maintenance task completion es in relation to equipment design. This method concentrates on predicting power expenditures. In addition, this method provides visibility to eduled/preventive maintenance and gives maintenance engineers and designers ool to aid in determining an appropriate design rationale for minimizing rall preventive maintenance time and cost. The procedures outlined in this ort apply to a wide range of preventive maintenance tasks and actions, and capable of being used during both early and later phases of system uisition.

An important component of these procedures for predicting preventive ntenance task times relates design features to task times such that design ideoffs can be made during concept development phases early in the uisition process. Once a system is designed and fabricated, redesign omes extremely costly and, therefore, is rarely done. A system designed h cognizance of preventive maintenance requirements will have lower life le costs.

The present study is part of a family of efforts to advance knowledge ' maintainability design and to derive methods to reduce maintenance costs ırough predicting and understanding them.

.2 Study Requirements

This study is part of a program initiated by RADC in response to the ɔncerns identified above. The study objective is the development of rocedures and techniques for predicting preventive maintenance manhours and ime required to keep electronic systems and equipments in operating ondition. Central to this objective was the requirement that these rocedures relate system and equipment design features and characteristics to equired maintenance manhours and to other time expenditures which result from reventive maintenance. The prediction techniques developed were to be apable of use during validation and full scale development acquisition phases.

Two types of data were required to be collected. One type was ngineering information which pertained to system or equipment design features nd characteristics that impacts preventive maintenance needs. The second ype was preventive maintenance manhour and time information related to 'arious specific types of preventive maintenance tasks. The data were to be aken from systems and equipments of varying types to yield a tatistically sound product and to accurately represent the electronic quipment population. On obtaining the data, relationships between design eatures and preventive maintenance task completion times were to be valuated. Finally, the product was to provide a prediction technique which

Subjective Estimation

As we examined other study alternatives our attention was drawn to a ' of work performed at Bell Telephone Laboratories over the past 10 years ›lving subjective estimation of work times. The following paragraphs ;ent a discussion of that research, and our reasons for adopting the jective estimation approach.

.1 Subjective Estimation Background

Tieger & Felfoldy5 have summarized studies regarding subjective imation techniques. Their research grew out of a Bell System need to imate maintenance times for tasks for management purposes and for legal port. However, the tasks to be estimated varied over immense ranges and e usually performed in environments not conducive to measurement. For mple, consider the task of installing an extra telephone extension outlet a subscriber's residence. The steps involved in this task could vary in ms of existing outlets, locations of drops, accessibility, exterior and erior construction materials, and other factors. Even if these factors ld be taken into account, the work is typically done by a single installer, , therefore, attempts to directly observe the work would be intrusive and ld affect data quality. Consequently, a subjective estimation technique developed by the Bell System to acquire otherwise unavailable data. dies and applications of the technique have indicated that accurate data be obtained through its use.

3.0 ESTABLISHING THE MAINTENANCE TASK TIME DATA BASE

In order to produce an accurate prediction technique, a data base reflecting more accurate input data needed to be developed. Two candidate methods for establishing a data base were evaluated, time and motion studies and subjective estimation techniques.

3.1 Time and Motion Studies

The industrial engineering literature is rich with a long history of time and motion studies[4]. Such studies apply vigorous measurement methodologies to tasks, often with the goal of redesigning the task and the system to optimize workers' output. To this extent such methodologies coincide closely with the objectives of this study. Two major factors however, limit its application as a general methodology. First, a useful method is one which can be used to evaluate proposed system designs in order to possibly verify them before the system is built. Time and motion studies, in order to be valid, must be performed after-the-fact and in that sense are no more useful than and serve the same purpose as existing M-demo methods. Second, if the goal of the present study is to relate design features to maintenance times, time and motion studies encompassing many design features would need to be performed involving enormous expense with little guarantee of success. Consequently, time and motion studies were dropped from further consideration.

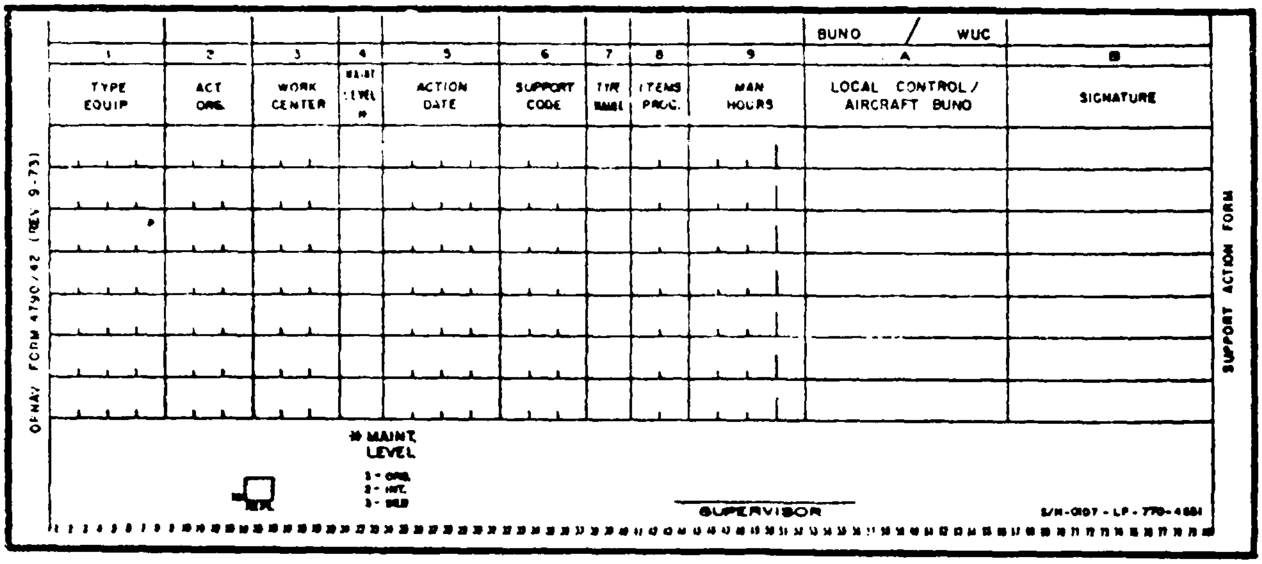
Considering these factors, we concluded that analysis of existing recorded data was impossible since the validity of such data could not be guaranteed. Even if the biases in the data could be studied in an attempt to correct them, we found that the biases themselves vary. Therefore, in the worst case, each data item in existing records would need to be verified independently, involving effort equivalent to performing timed measurement of all possible items.

2.1.3 Harris Calibration Laboratory

Another source of PM data was the Harris Calibration Laboratory, patterned after the Air Force PMEL's. The only scheduled maintenance task performed at the Harris Cal Lab was calibration, unless other tasks, such as cleaning, were specified by the equipment manufacturer for proper operation. Time actually spent calibrating equipment was not recorded but guidelines were set by Technical Order Manual 33K-1-100. This manual lists average calibration times for various electronic equipments, similar to PMI or MRC cards. Again, while these data are useful for Cal Lab administrative purposes, they were of limited utility for this effort.

2.1.4 Evaluation of Data Environment

According to the expert maintainers' interviewed, preventive maintenance procedures, periodicity, and approximate times to complete tasks were taken from equipment manufacturer's specifications and modified. PM manhours that were recorded, and in most cases they were not, were inflated or reflected expected standard times and not actual task completion times. The primary lessons learned from our examination of the field data environment were that: (1) data collection systems, forms, and methods vary widely among sites and commands; (2) data are not always recorded; and (3) when data are recorded, they are often overestimated or underestimated depending upon local practice and other reasons.



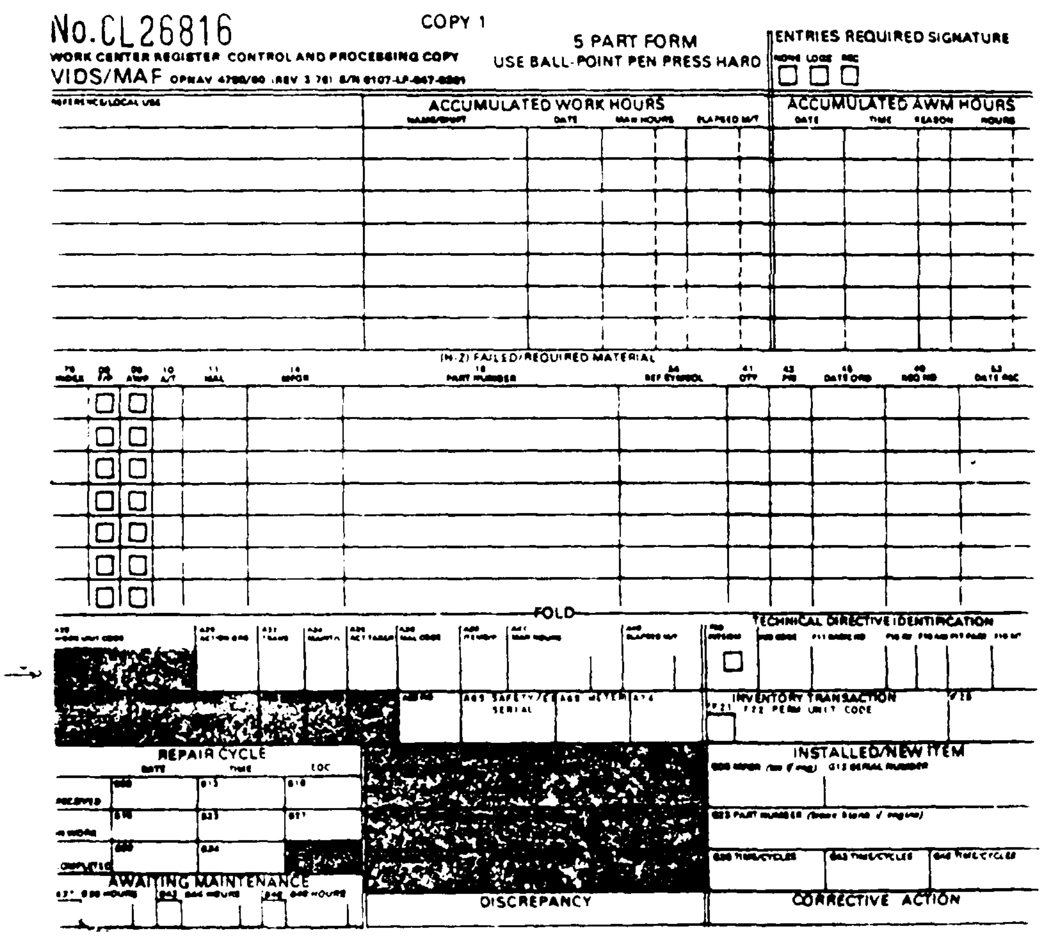


Figure 2.1.2-2 Navy Maintenance Data Collection Forms

<table>
<tr><td rowspan="2">Man Min-utes</td><td rowspan="2">Work Area</td><td rowspan="2">Card No.
2.3</td><td>DPR</td><td>NAVTRADEV P-4128</td><td rowspan="2">Electrical Power
☒ ON ☐ OFF ☐ N/A</td></tr>
<tr><td colspan="2">MOTION SYSTEM MECHANICAL AND ELECTRICAL CHECK</td></tr>
<tr><td>:02</td><td>47</td><td colspan="4">13. Look for leakage in the following hydraulic pumping equipment, check fluid level in reservoir and position of inlet/outlet valves:
a. Motion pump units
b. Control loading pump unit
c. Boost pump
d. Hydraulic fluid reservoir
e. Water heat exchanger
f. Return link filters</td></tr>
<tr><td>:01</td><td>49</td><td colspan="4">14. Observe the ten FILTER indicator lights on the HYDRAULIC POWER MASTER CONTROL panel. Illumination of any of these lights indicates the respective filter elements(s) must be changed.</td></tr>
<tr><td>:01</td><td>47</td><td colspan="4">15. With the hydraulic system pressurized, inspect for normal operation by checking that the pressure gauges read 1200 psi.

Continued</td></tr>
</table>

Figure 2.1.2-1 Navy Maintenance Requirement Card

MAINTENANCE DATA COLLECTION RECORD								OMB NO. 21-R0227
1. JOB CONTROL NO.	2. WORKCENTER	3. I.D. NO./SERIAL NO.	4. MDS	5. SRD	6. TIME	7. PRI	8. SORTIE NO.	9. LOCATION
10. ENG. TIME	11. ENGINE I.D.	12. INST ENG TIME	13. INST. ENG. I.D.	14.	15.	16.	17. TIME SPC RFQ	18. JOB STD.
19. FSC	20. PART NUMBER	21. SER. NO./OPER. TIME	22. TAG NO.	23. INST. ITEM PART NO.		24. SERIAL NUMBER		25. OPER. TIME

ACT. LINE	A TYPE MAINT	B COMP POS	C WORK UNIT CODE	D ACTION TAKEN	E WHEN DISC	F HOW MAL	G UNITS	H START HOUR	I STOP DAY	I STOP HOUR	J CREW SIZE	K CAT LAB	L CMD ACT ID	M SCH CODE	N AFSC/EMPLOYEE NUMBER
1															
2															
3															
4															
5															

26. DISCREPANCY	
27. CORRECTIVE ACTION	
	28. RECORDS ACTION

AFTO FORM JAN 81 349 PREVIOUS EDITION WILL BE USED

DEFENSE METEOROLOGICAL SATELLITE PROGRAM – PREVENTIVE MAINTENANCE SCHEDULE							
7 DAY	14 DAY	28 DAY	56 DAY	84 DAY	168 DAY	ANNUAL	DAILY
WORK AREA CODE		NOMENCLATURE		INSPECTION REFERENCE			
DATE	COMPLETED BY	DATE	COMPLETED BY	DATE	COMPLETED BY	DATE	COMPLETED BY

DMSP PMS FORM, AFCS 110, EXEMPT FROM 66-5

Figure 2.1.1-1 Air Force Maintenance Data Collection Forms

cases the time allocated was excessive given the steps required for the preventive maintenance task. Examples of Air Force maintenance data collection forms are shown in Figure 2.1.1-1. Maintenance data collected using these forms are usually stored on the base for reference.

Most maintenance programs appear to include the same basic steps. These steps guide the maintainer in performing preventive maintenance tasks and in recording maintenance data.

2.1.2 Navy

The Navy maintains a Planned Maintenance System (PMS) which is part of the Maintenance, Material, Management (3M) system data base. The 3M system is separated into shipboard and avionics sections. For each equipment, a series of Maintenance Requirement Cards (MRC), as shown in Figure 2.1.2-1, are available to assist the maintainer in performing maintenance procedures. Time spent on PM tasks may be entered on a number of forms, depending on the base and systems involved. Examples of Navy maintenance data collection forms, as shown in Figure 2.1.2-2, include the Support Action Form and the Visual Information Display System/Maintenance Action Form (VIDS/MAF). However, like the Air Force, accurate times to complete PM tasks could not be derived from the forms. Since the data collection methods used by the Navy were similar to Air Force methods, the Navy 3M data base was not used as a data source for this study.

2.1.1 Air Force

Surveys of preventive maintenance data and procedures were taken at four Air Force installations, including Patrick AFB, MacDill AFB, Edwards AFB, and Offutt AFB. The purpose of these surveys was to evaluate Air Force maintenance data sources and procedures. To collect this information, maintenance documents were reviewed and maintainers were consulted. The common Air Force Maintenance document was the Air Force AFSC 66-1 handbook which is used as a guideline for maintenance procedures by some installations. The handbook is divided by classes of equipment (e.g. avionics, communications) but used primarily for corrective maintenance. Classes of equipments are assigned to various commands. A systems or maintenance manager at each base is responsible for a particular equipment or stock class. For example, at Patrick AFB, the Consolidated Aircraft Maintenance Squadron (CAMS) performs maintenance on specific classes of avionics equipment. Other forms of Preventive Maintenance, such as calibration, are performed by a Precision Measurement Equipment Laboratory (PMEL), usually located elsewhere on the base. Some Air Force Programs, such as the Defense Meteorological Satellite Program (DMSP), have maintenance programs which do not follow the AFSC 66-1 system found on other bases.

One reference mechanism commonly used by the Air Force to allocate preventive maintenance tasks is a set of maintenance cards. The cards, termed PMI (Preventive Maintenance Instructions), list the task to be performed, task periodicity, and predetermined task completion times. Task descriptions listed on the cards that were evaluated in our fact finding were in most cases ambiguous and did not contain sufficient detail. We also found that in most

2.0 FIELD DATA ENVIRONMENT

2.1 Existing Data Base Examination

Because preventive maintenance is an integral part of maintaining electronic equipment, it was initially assumed that task completion time data were collected by the Air Force and other services as well as by contractors. However, in reviewing a number of maintenance data sources and interviewing field maintenance technicians, we determined that no organization consistently or accurately recorded PM information in sufficient detail to meet the study requirements. The time data available to us were inadequate for purpose of this study, because, in most cases the recorded time to complete a preventive maintenance task included the total time from taking the equipment off line until placing it back on line. This "total time" included many extraneous factors not specifically related to the actual preventive maintenance task. For example, these times reflected the time the equipment was waiting to be maintained due to lack of maintainer availability, and included times where the maintainer was performing other tasks. In other words, the available data were inadequate for quantitative data analysis and manipulation required to develop a prediction technique.

In order to determine the existence and size of the preventive maintenance data base and to determine data collection methods and sources, procedures were examined within three organizations. These organizations were the Air Force, Navy, and Harris Field Operations.

with maintenance supervisors whose judgements could guide further data collection and analysis. This capitalized on the fact that site personnel have an understanding and intuitive feel for significant data which otherwise would take years of formal data analysis and modeling to uncover. In fact, as indicated in the following methodology and data collection sections of this report, we demonstrate that data collected from maintenance experts were reliable and valid and could be used to develop prediction techniques consistent with the purpose of this study.

To derive relationships between SPMA design characteristics and time requirements, several data analysis techniques were used. These included simple descriptive statistics, correlational analysis, and multiple regression. The results were used to create the products for predicting preventive maintenance task completion times. The final product consists of a regression equation, a prediction algorithm, and design feature tables. Other products, not provided in this study, such as flow chart decision aids, decision tables, or software tool development guidelines could also be derived from the results.

Our approach to product validation was revised early in the study to accommodate limitations we found in the field data environment. The validity of the prediction algorithm was verified using a subsample of the study data base.

were obtained. This process formed the foundation for the remainder of the study. A significant portion of early study activities, therefore, revolved around learning about preventive maintenance, particularly through literature surveys and in-depth interviews with experienced maintenance personnel.

Concurrent with data collection in the early phases of the study was an evaluation of the adequacy of the current PM data base. Records were examined in order to derive information relevant to the study, most notably information regarding manhours expended as a function of PM. Several sources were identified for use in this phase of data collection, primarily Air Force and Naval Bases.

Early in the data collection process we expected to obtain four classes of data: (1) actual maintenance times, personnel requirements, and tool and equipment resources which describe and estimate the cost of SPMA's, (2) failure and degradation data related to the success of SPMA's, (3) design characteristics which comprise the interface to the maintainer, typically at the equipment and chassis level, and (4) design characteristics related to the environment in which the to-be-maintained equipment or chassis resides, typically within racks, cabinets or shelters. However, due to the field data environment, only actual preventive maintenance times, estimated maintenance times, and design characteristics data were obtained. The data were collected in a form suitable for both qualitative and, when appropriate, quantitative analysis. Our goal and practice was to collect significant amounts of data quickly, efficiently, and inexpensively. This allowed sufficient time for appropriate analysis and review of preliminary findings

to implement and (2) accurately predict system downtime due to preventive maintenance. The Harris study team identified the following study objectives necessary to develop the methodology and satisfy the above criteria:

1. Identify a set of Scheduled/Preventive Maintenance Actions (SPMA's).

2. Collect SPMA time and manhour data and validate the list of SPMA's previously identified.

3. Evaluate two types of design characteristics, those that relate to SPMA performance and those that define the system.

4. Identify relationships between SPMA, design characteristics, system characteristics, and time or man-hour requirements.

5. Develop the final products (prediction & analysis techniques) and validate them via sample application.

To accomplish these objectives, the study team implemented a field survey specifically oriented toward the collection of SPMA data. During this process, general maintenance knowledge and samples of task completion times

could be used for estimating maintenance manhour expenditures as a function of the design characteristics and makeup of a system. The technique was to be structured for application during the validation and full scale development phases of system and equipment acquisition.

In completing the RADC program, the following requirements were met. First, maintenance tasks and actions defined as being preventive maintenance (e.g., calibration, performance checks, scheduled replacement of parts, etc.) were identified. Second, engineering data pertinent to electronic system and equipment design features which impact preventive maintenance manhours were collected. These data were representative of avionic and ground based systems and equipments. The data allowed for the identification of the specific nature of the preventive maintenance task, the identification of maintenance manhours that resulted from each maintenance task, and the correlation of time data to specific equipment design features. Third, relationships between design features which impact preventive maintenance tasks and the manhours and time necessary to implement such tasks were identified. Finally, the resulting relationships and correlations were used to develop prediction tools which, when applied, could aid in estimating preventive maintenance manhours and times for electronic equipment.

1.3 Study Plan

The primary goal of this study was to provide RADC with a methodology which, when applied during early system acquisition phases, would permit an engineer to: (1) make design characteristic trade-offs while still economical

Our interpretation of each of the general components of the Bell subjective estimation techniques follow.

3.2.1.1 Work Breakdown Analysis

Work breakdown analysis was defined as a detailed task analysis performed to the lowest reasonable level to which an overall task can be reduced. This may be derived from engineering drawings, examination of equipment, interviews with experts who have performed the tasks and know the steps involved, or procedural manuals. In general, when a task has been broken down to a level where it can be represented in flowchart form, including all optimal steps, the analysis is sufficient. We present our refined definition of subtask "elements" in terms of an "action design features" (A/DF) syntax.

3.2.1.2 Subjective Estimation

Data were collected from panels of expert maintainers via forms which present the elemental PM subtasks and ask for minimum, most likely, and maximum estimated times, where minimum (MIN) is the absolute minimum time to perform under optimal conditions, most likely (ML) is the typical time, and maximum (MAX) is the maximum time to perform under worst conditions but barring catastrophes. In the Bell studies these times were beta-weighted according to the equation:

$$\overline{T_{pm}} = [MIN+(4xML) + MAX]/6$$

This provided averages weighted toward the most likely estimate. In our own studies, however, minimum and maximum tended to vary symmetrically and, therefore, we used only the most likely estimate to compare to the actual task time.

3.2.1.3 Aggregation

Elemental estimated times were summed to obtain an aggregate time. For tasks with optimal or required subtasks, the subtasks may be weighted by their probabilities of occurance. Most of the PM tasks did not contain optional subtask procedures to be performed at certain points in the completion of the main task. In our studies, no optional subtasks or steps within a PM procedure were considered. However, the flowcharting referred to in the task analysis phase above can be used to accommodate optional subtasks, if the subtask branches are labeled with associated probabilities when the chart is developed.

3.2.1.4 Validation

The summed whole-task estimates were compared with actual task completion times. The actual times were either observed or from "book standards". Linear product moment correlations are the best means for showing the degree of fit of estimates to actual times (no statistically reliable non-linear relationships have been found by Bell or Harris for this type of data). The Bell studies typically found correlations in the $r=0.7$ to $r=0.9$ range; while the present studies yielded correlation coefficients greater than 0.9.

After validation, it may be concluded that estimates and actuals covary but this does not mean that the estimates can be used directly in predicting PM Task completion times. In both the studies, experts tended to overestimate individual subtask times by a factor of 1.5 to 2.0. The analysis and validation results described in the data analysis section of this study show how these biases can be taken into account, corrected, and used to develop estimates which are very close to actual times.

3.3 Lessons Learned in Pilot Studies

Since subjective estimation was identified as the best candidate methodology for the study, some means for evaluating its relevance to study goals was desired. An ideal way to test the methodology was to apply it to a sample of equipment and maintainers to evaluate how efficiently it could be used to predict actual work times. If the results of these pilot applications were promising, a more detailed study could be conducted whereby prediction algorithms could be developed.

The subjective estimation methodology was pilot tested at three locations: Harris PMEL, MacDill AFB, and Patrick AFB. Results of these pilot studies provided strong support for using subjective estimation to predict task times. The analysis revealed an extremely high correlation between actual task times and estimates provided by expert maintainers. Given the very supportive results obtained from the pilot tests, we developed a data collection methodology.

4.0 DATA COLLECTION METHODOLOGY

4.1 Introduction

This section describes the data collection methodology used in this study. The methodology was developed to provide a systematic procedure for identifying data sources, selecting representative subjects and equipments, and collecting accurate and meaningful data. Working from the general hypothesis that maintainers can predict actual preventive maintenance task times, a methodology was established to precisely evaluate independent and dependent variables related to preventive maintenance. Figure 4.1-1 presents elements of the data collection methodology.

4.2 Equipment Database

The primary objective in forming an equipment database was to select a representative sample of equipments used by the Air Force which have established PM tasks and which represent avionics and ground based electronics. Other criteria used to select equipment were accessibility and frequency of PM tasks performed. In addition, it was desirable to choose equipment sites where maintenance personnel were available. Five classes of equipment were identified: test equipment, telemetry equipment, communications equipment, computer equipment, and avionics equipment. A detailed breakdown of selected equipments with associated source, class, and PM task descriptions is provided in Table 4.2-1.

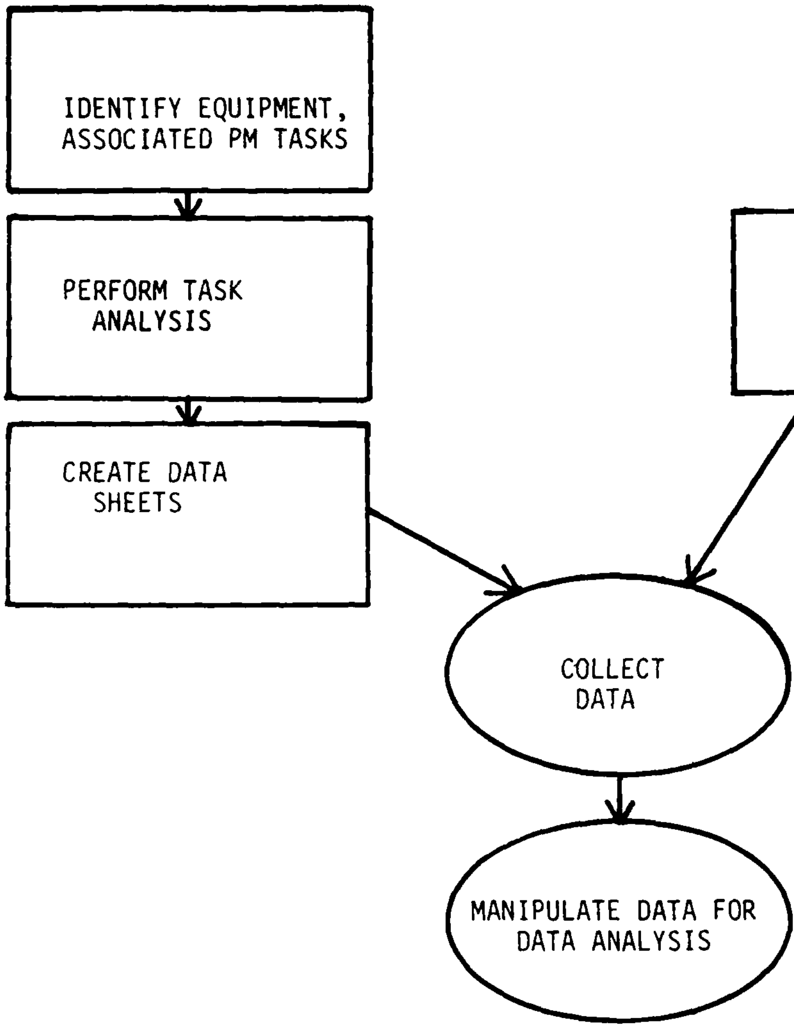


Figure 4.1-1 Data Collection Methodology

SOURCE/ SYSTEM	CLASS	EQUIPMENT	SPMA
HARRIS PMEL	TEST EQUIPMENT	VOLTMETER SIMPSON 260 OSCILLOSCOPE TEK 475A POWER SUPPLY POWER DESIGN SIGNAL GEN WAVETEK 142 COUNTER HP 5245L SWR METER HP 415E	CALIBRATE
OFFUTT AFB, GLOBAL WEATHER	COMPUTER, COMMUNICATIONS, TELEMETRY	CHASSIS/PANEL (COMM/TELE) CHASSIS/PANEL (COMM/TELE) CONSOLE/RACK (COMM/TELE) COMPUTER DG NOVA 4 DISK DRIVE DG 6050 MAG TAPE UNIT AMPEX MAG TAPE UNIT DG 6026 DATA FORMATTER POWER SUPPLY POWER SUPPLY (DUAL) POWER SUPPLY (QUAD) FILM PRINTER CDM-3	MONITOR, PERFORM ALIGN INSPECT, CLEAN REPLACE PARTS SERVICE
PATRICK AFB, CONSOLIDATED AIRCRAFT MAINTENANCE SQUADRON	AVIONICS	O-2 ANTENNA SYSTEM O-2 COMM/NAV CHASSIS O-2 CONTROL BOXES OV-10 ANTENNA SYSTEM OV-10 CONTROL BOXES OV-10 RX/TX UNIT VHF(FM)	INSPECT, CLEAN MONITOR, PERFORM
MACDILL AFB, MARK IV MOBILE WEATHER TERMINAL	TELEMETRY, COMMUNICATIONS, COMPUTER	ANTENNA HYDRAULICS TAPE TRANSPORT SOFT COPY UNIT DIESEL GENERATOR SET ENVIRONMENTAL CONTROL UNIT	MONITOR, PERFORM INSPECT, CLEAN ALIGN SERVICE

Table 4.2-1 Selected Equipment Breakdown

4.3 Task Analysis

For each equipment selected, associated PM tasks were extracted and broken down into discrete task elements. We derived these PM task elements by reviewing equipment manuals and work cards, and by observing maintainers. Early in the study, task analyses were performed to outline major subtasks (e.g. remove cover, calibrate voltage, close cover). It was later determined that a more detailed level of subtask analysis would lead to precise subjective estimates which more closely approximate actual task completion times. To obtain these precise breakdowns, subtasks were reduced to a series of specific action and associated design feature steps (A/DF steps) as illustrated in Table 4.3-1.

4.4 Subjective Estimate Data Sheets

Subjective estimate data sheets were developed from the task analyses. Each data sheet included the equipment name, equipment type, periodicity of PM being performed, and subtask descriptions. Next to each subtask description, spaces were provided for experts to subjectively estimate the times associated with subtasks. The worksheet format required the experts to provide three estimates: the minimum or best case time, the maximum or worst case time, and the most likely or typical time it would take to complete the PM subtask.

Data sheets were constructed for purposes of collecting both major subtasks and detailed design feature task times. A sample data sheet is presented in Figure 4.4-1.

SUBTASKS	ACTION/DESIGN FEATURE STEPS
Remove Cover	- Remove 4 2" screws with flat washers - Remove 4 knobs, pulling off from front panel - Remove front panel cover
Calibrate Voltage	- Connect two test probes to test points on edge of circuit card - Measure voltage - Adjust variable resistor in center of circuit card to $\pm$ 12 VDC - Remove two test probes from test points on edge of circuit card
Close Cover	- Place front panel cover on chassis - Place 4 knobs on front panel (press-fit) - Place 4 2" screws with flat washers into screen holes - Tighten 4 2" screens with flat washers until all are secure.

Table 4.3-1 Subtask Breakdown

ESTIMATOR FORM -- PMI STUDY

Design Features Study

EQUIPMENT ITEM OV-10 Aircraft COM Avionics (Cont.)

TECH ORDER REFERENCE Word Card No 1-034

PM TASK NAME Inspect, Clean, Tighten, etc.

TASK PERIOD Phase

ACTION	DESIGN FEATURE	Estimated Time (Seconds) Min	Max	Best Guess
INSPECT	COM/NAV elect. system chassis in rear of airplane to ensure that jumbers, grounds, and terminal strip connections are not corroded, damaged or loose.	30	90	60
INSPECT	Black box to ensure there is no damage or corrosion, that it is clean and secure, and that the shock isolator mounts are not deteriorated.	30	90	60
REPLACE	Black box in rack at rear of airplane (slide in).	5	10	7
TIGHTEN	One ARINC fastener to secure black box to equipment rack.	2	4	3
TIGHTEN	Two ARINC fasteners to secure black box to equipment rack.	4	8	6

Figure 4.4-1 Sample Data Collection Work Sheet

4.5 Subject Population

Subjects were experienced maintainers selected from various equipment sites. Subjects were placed in one of two groups depending on their maintenance experience. Specifically, maintainers who directly performed PM on selected equipment on a routine basis were labeled "familiar" maintainers. Maintainers with general preventive maintenance experience, but who did not maintain the selected equipment, were identified as "generic" maintainers. In some cases, a "familiar" maintainer on one set of equipments may have been a "generic" maintainer on other equipments.

4.6 Data Collection

4.6.1 Subjective Estimates

Subjective estimates were collected from maintainers at various equipment sites. Subjects were asked to read each subtask description carefully and to estimate the minimum, maximum, and most likely task completion time per subtask. Subjects were advised to follow the time convention established on the form. Depending on the level of sub-task breakdown, the easiest time convention to use, either minutes or seconds, was adopted. Equipment manuals and pictures were available for reference. Subjects were told to estimate each subtask independently of all others.

4.6.2 Task Time Measurement

To develop a predictive algorithm, the actual time to complete a PM task had to be measured. Actual PM performance times were obtained by unobtrusively observing maintainers and recording their times to complete tasks. Measurements were made using a stopwatch.

5.0 DATA ANALYSIS

5.1 Statistical Analysis of Data

In order to develop a prediction model, the raw observed and estimated PM task completion time data were transformed into manageable form via descriptive statistics. Using the transformed data, linear product moment correlations were computed to assess the relationship between actual measured task times and several independent measures. Since correlational analysis revealed a strong, positive relationship between observed and estimated task completion times, linear regression analysis was performed to derive a single prediction algorithm.

5.2 Early Activities

Two sources of data were evaluated to determine their potential utility for developing a prediction algorithm. First, standard times taken from military (Air Force) standard work cards corresponding to several pieces of equipment were compared to actual measured task times associated with maintaining equipment. Results of this analysis revealed that no statistically significant relationship existed between observed and standard times allocated for preventive maintenance, $r(4) = .35$, $p > .05$. Second, the number of sub-tasks comprising the overall task of maintaining equipment was identified. Again, no statistically reliable relationship between the number of discrete steps and the time to complete the task was found, $r(4) = .64$, $p > .05$.

2.1 Pre-testing the Subjective Estimation Methodology.

Since no relationship was found between actual task time and time :andards or number of task steps, subjective estimation techniques were used ɔ determine how well maintainers could estimate maintenance task completion imes. Consistent with the data collection methodology, time estimates were ɔllected from both familiar and generic maintainers. For the purpose of ɔtaining a consolidated estimate, these task times were summed and the esulting totals were compared to actual times required to perform the reventive maintenance tasks. When compared to actual task completion times, amiliar maintainers' estimates correlated very highly, r (9) = .95, $p < .01$. eneric maintainer's estimates also correlated very highly, r (9) = .89, $< .01$. In addition, estimates provided by the familiar maintainers orrelated significantly with those provided by the generic maintainers, (9) = .95, $p < .01$. Although this relationship is strong, it was found that stimated times provided by generic maintainers were consistently longer in uration than those provided by familiar maintainers. A test of interrater eliability was also performed, and revealed that raters were very consistent n their ratings. That is, when retested, raters second subtask estimates ere, on the average, within 90% of their original estimates.

.2.2 Data Treatment

Given the significant results which supported the subjective stimation methodology, data were collected and analyzed which related pecific equipment design features to associated preventive maintenance tasks.

.4.1 Validation Phase

In this phase, the system or equipment development contract ically requires an engineering development model (EDM) and an advanced elopment model (ADM). The equipment manufacturers' responsibility is to onstrate that the conceptual functions can be reduced to practice. ever, design information is not yet detailed.

.4.2 Full Scale Development Phase

In this phase, the contract usually involves converting the ceptual model into an actual equipment or system. Design details become ilable and support resources are defined in this phase. Also, lt-in-test (BIT) is incorporated into the design.

.5 General Use of Products

The two products use the available level of design detail to imate the time and personnel resources needed for preventive maintenance. principles underlying each predictive method are the same. The ntainability engineer must know which tasks are needed, analyze each task a depth consistent with level of design, assign weighted factors to ments of the analysis, fit the aggregated factors into the appropriate lel and document the results for each task. Figure 6.1.5-1 illustrates the ocess.

The following items have been identified as administrative functions. The maintainer must:

(1) determine what support items or supplies are needed.

(2) gather needed items.

(3) allow any test equipment or the unit-under-test to warm up.

(4) after task completion, put away all support items.

(5) dispose of waste materials.

(6) make required entries on maintenance records.

(7) complete required work orders for corrective maintenance.

Active time includes the time needed to actually perform the preventive maintenance. The following items have been identified as active time functions. The maintainer must:

(1) gain access to the equipment.

(2) perform the required PM task elements.

(3) close the unit.

(4) check unit operability.

6.1.4 Acquisition Phase Products

Two products were developed, one for each of two phases of the government acquisition process. The acquisition phases are the Validation Phase and the Full Scale Development Phase.

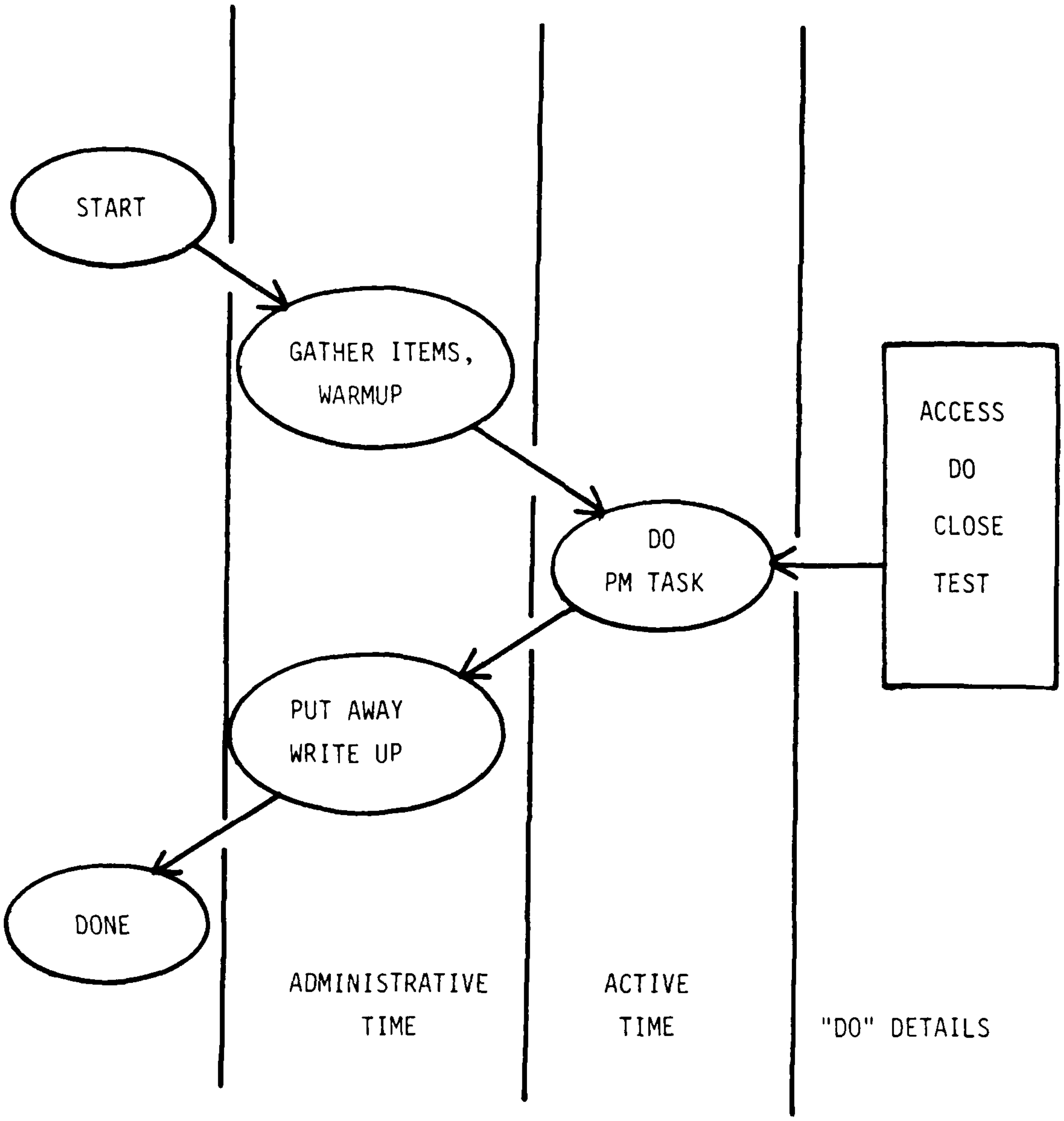


Figure 6.1.3-1 Typical Preventive Maintenance Task Flow

SPMA CATEGORY

GENERIC TASK	CALIBRATE	MONITOR PERFORM	ALIGN	INSPECT AND CLEAN	SCHED. PART REPLACE	SERVICE
ADJUST TASK	●		●			
CLEAN TASK				●		
INSPECT TASK		●		●		●
LUBRICATE					●	●
MEASURE TASK	●	●	●			
REPLACE TASK					●	●
TEST TASK	●	●	●			

Table 6.1.2-3 Relationship Between SPMA and Generic Preventive Maintenance Tasks

TASK TYPE	DEFINITION
ADJUST	Bring to specified position or to more satisfactory state.
CLEAN	Wash, scrub, remove residue, rinse, dry etc.
INSPECT	Do critical observation, look, listen or feel for specific conditions, evaluate wear, etc.
LUBRICATE	Apply lubricant on or in specified places.
MEASURE	Determine dimensions, capacity, amount, levels or shapes.
REPLACE	Restore to former place or position or substitute servicable item for like item that is damaged, worn out, or malfunctions.
TEST	Verify operational readiness by doing specified operations.

Table 6.1.2-2 Definitions of Generic Maintenance Task Types

SPMA	DEFINITION
CALIBRATE	Transfer measurement standards to precision measuring equipment, Built-In-Test circuits, Built-In-Test equipment, and to some metered tools. Usually a function of a PME Lab but may be a task for complex systems maintainers.
MONITOR PERFORMANCE	Inspect, Test, or Measure to determine item compliance with expected standard characteristics. Usually done to detect incipient failure.
ALIGN	Adjust paramaters to more desirable values, although measured values are not outside specified acceptable range.
INSPECTION & CLEANING	Removal of dirt, corrosion, residue, etc., which might cause deterioration of operation.
SCHEDULED PART REPLACEMENT	Replacement of a serviceable item with a new item, based only on the completion of a specified number of hours, days, miles, rounds, etc.
SERVICE	Replace, or restore to desired level, consumables such as coolant, charts, hydraulic fluid, rolls of paper, application of lubricants, etc.

Table 6.1.2-1 Definitions of SPMA Categories

actions. Preventive maintenance tasks are inclusive and are named for the primary activity accomplished by the task. Table 6.1.2-1 contains the definitions of the six SPMA catagories identified in the study. Table 6.1.2-2 contains the definitions of the seven task types. The relationship between the seven tasks and the six SPMA is shown in Table 6.1.2-3.

6.1.3 Preventive Maintenance Task Flow

We identified the common elements of a preventive maintenance task and defined a typical task model. Common elements of scheduled and preventive maintenance tasks account for both administrative time and active time, however, of two products developed in this study, the VAL phase model predicts both elements whereas the FSD predicts only active task completion time. Thus, the maintainability engineer may capture both the personnel time resources and equipment downtime resources inherent in each PM task. Each PM task starts when the supervisor assigns a task to a maintainer. The task ends when the maintainer has finished the task, has put away all items used, cleaned up the area, and completed all required records. Figure 6.1.3-1 illustrates the flow of a typical preventive maintenance task. The figure depicts the general steps in the administrative and active parts of a task.

Administrative time is a function of the particular characteristics of the maintenance facility, such as layout and policies. Generally, administrative task completion time remains relatively constant while active task completion time varies over a wide range. The ratio of active to administrative time would typically increase as task complexity increases.

6.0 PRODUCT DEVELOPMENT

6.1 Overview and Terminology

6.1.1 Overview

The products developed in this study apply to two phases of the military acquisition process, Validation (VAL) and Full Scale Development (FSD). Each product was developed with the expectation that it would be used by engineers experienced in maintainability and logistic support. The value of these products will become apparent in planning, allocating resources, and in comparing alternative design approaches. In the VAL phase, the maintainability engineer must work with limited design information, conceptual design guidelines and goals, and a conceptual support system definition. In the FSD phase, the maintainability engineer is provided more detailed design information and firmer system definition. In considering the prediction of scheduled and preventive manhours, there is a difference between the VAL model and the FSD model. The VAL Phase considers both the active or actual task completion time and the administrative task completion time. The FSD Model, since it provides explicit design information considers only the active task completion time.

6.1.2 Terminology

In the development of these products, we have differentiated between Scheduled Preventive Maintenance Actions (SPMA) and preventive maintenance tasks. SPMA refers to categories or classes of preventive maintenance

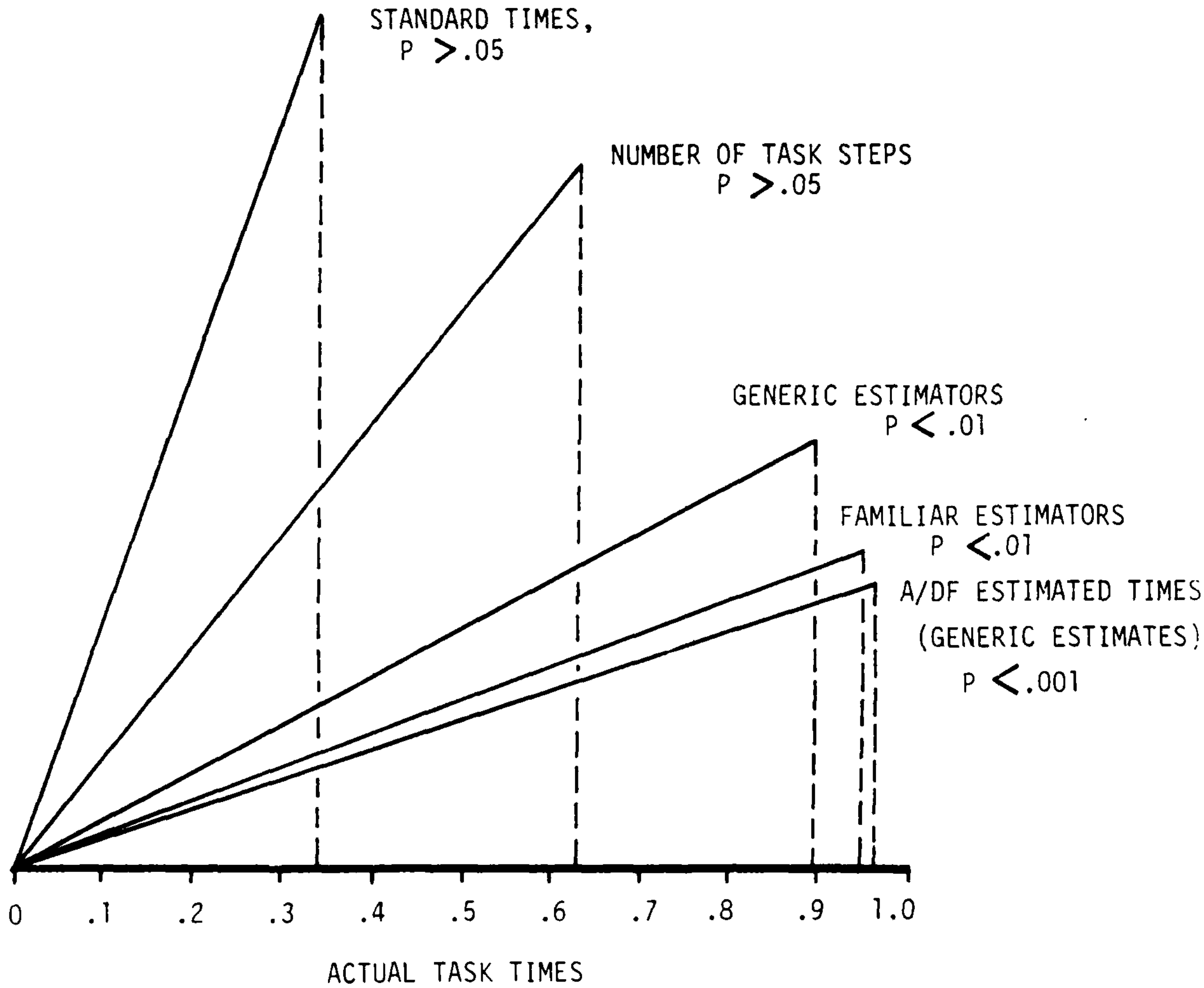


Figure 5.3.1-1 Correlation of Actual Task Completion Times vs. Various Independent Measures

5.3 Discussion of Results

5.3.1 Early Findings

A geometric representation of the overall results is presented in Figure 5.3.1-1. To summarize, a strong relationship was found between familiar maintainer estimates and actual times as well as between generic maintainer estimates and actual times (in addition, a strong correlation was found between familiar maintainer estimates and generic maintainer estimates). When compared to actual task times, both military standard task times and number of discrete task steps revealed no relationships. These results strongly supported our use of generic maintainers as a source for building a data base of task times.

5.3.2 Generic Estimates of Design Features

Figure 5.3.1-1 also indicates a strong relationship between summed generic maintainer estimates based on action/design feature subtasks and actual PM task times. Consistent with early findings, it is evident that more detailed PM task breakdowns improve the relationship between generic maintainer estimated times and actual times.

From this base of times provided by generic maintainers, and our very supportive results, products were derived which can be used in two phases of acquisition, validation and full scale development.

ORIGINAL ANALYSIS (N=29)

$R = 0.96 \quad R^2 = 0.92$

$LOG^Y = (1.03)\ (LOG^{A/DF}) - 0.12$

$S_{XY} = 0.222$

$S_Y = 0.785$

STANDARD ERROR RATIO = 3.53: 1

VALIDATION ANALYSIS (N=22)

$R = 0.96 \quad R^2 = 0.92$

$LOG^Y = (1.02)\ (LOG^{A/DF}) - 0.11$

$S_{XY} = 0.239$

$S_Y = 0.854$

STANDARD ERROR RATIO = 3.57: 1

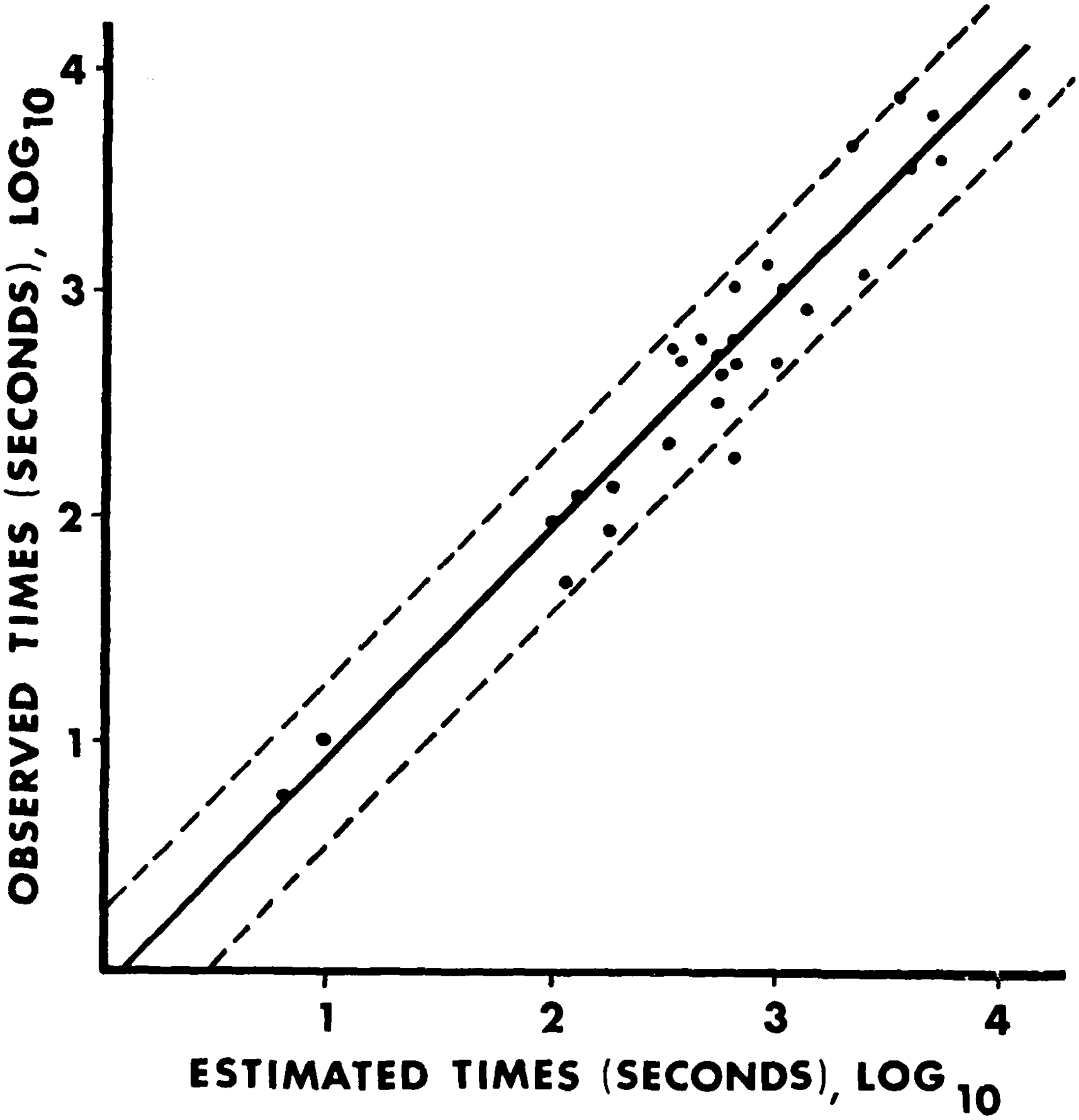
Table 5.2.2-1 Validation of Data Analysis

correlational analysis, $r(27) = .96$, $p < .001$. In addition, 95% confidence intervals, represented in the figure as dashed lines, were computed. All but one of the data points fall within the 95% confidence limits. Further analysis revealed that 68%, or one standard deviation, of the estimates are within .222 log of actual times. Linear regression analysis of the data resulted in the following equation, where T equals task completion time:

$$\mathrm{LOG}_{10}\ T_{actual} = 1.03(\mathrm{LOG}_{10}\ T_{estimated}) - 0.12$$

Supported by the strong relationship between A/DF estimated times and actual times, and the derived regression formula, a model was developed for applying the subjective estimation technique for predicting PM task completion times. But first, to test the robustness of the regression, a sub-sample validation was performed. To accomplish this, data representing 7 of the 29 equipments were removed randomly from the data set. The correlation and regression analysis were then performed a second time using only the 22 remaining equipments. It was assumed that if the regression was truly robust, removing items from the data set would not significantly alter the regression values. Results of this validation analysis strongly supported this hypothesis and yielded virtually identical values, shown in Table 5.2.2-1.

Inspection of these values, when compared to the values obtained from all 29 equipments, suggest little or no change in the slope, intercept, or correlation coefficient. Supported by this post-hoc analysis, the data obtained subjectively from generic maintainers were considered to be valid, and were therefore used to create a data base for use in the development of our predictive models and final products.



$R = 0.96$, $R^2 = 0.92$

SLOPE = 1.03

Y INTERCEPT = -0.12

$S_{XY} = 0.222$, $S_y = 0.788$

Figure 5.2.2-1 Actual Task Times vs. Subjective Estimates

In accordance with the data collection methodology, a group of generic maintainers provided estimates of times associated with individual design features derived from 29 equipments. Prior to summing elemental task times associated with each equipment for comparison with actual task times, the harmonic mean of estimates provided by maintainers was calculated. The formula for the harmonic mean applied to estimates was:

$$\overline{M_h} = \frac{N}{\frac{1}{X1} + \frac{1}{X2} + \ldots \frac{1}{XN}}$$

The harmonic mean was used to correct for a positively skewed distribution of estimates and to keep extreme or outlying estimates from artificially altering the true estimate. Once the estimates were harmonically averaged, a table of design features and associated times was created. Using the table as a guide, the PM tasks for each equipment were reconstructed by sequentially listing the proper action/design features and the corresponding times. These action design feature times were then summed for each equipment to achieve a total estimated time.

Prior to analyzing the relationship between these aggregate design feature estimates and actual times, the data were converted using common logarithms. This not only permitted a convenient way to graphically present the data, but also reduced the bias resulting from the broad range of time values (e.g. from 10 to 10,000 seconds) on both axes. The data resulting from the combination of harmonically averaging the estimates and converting sums to common logarithm form are presented in Figure 5.2.2-1. Inspection of this figure reveals a strong linear relationship which was supported by

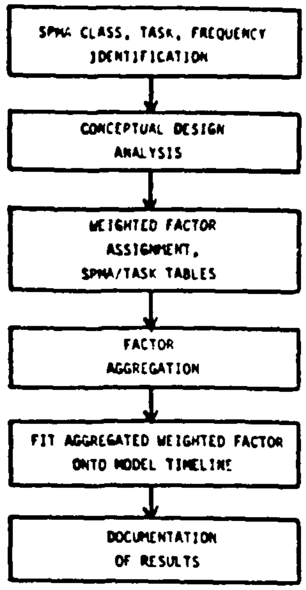


Figure 6.1.5-1 Common Process Flow for the Products

After deriving an estimate of task completion manhours for a system or equipment from either product, the annual PM manhour expenditure can be calculated by applying the results to a rudimentary model. The algorithm that determines total PM workload for a given time period is expressed as:

$$A_{TOTAL} = \sum \left[T_{act + adm} (F)(N) \right]$$

where A_{TOTAL} is the total number of manhours for the period, $\sum$ is the summation of all PM tasks for a system or equipment, F is the frequency of the task, $T_{act + adm}$ is the task completion time with separate active and administrative time components, and N is the number of personnel needed for task completion. Annual PM downtime may also be determined by a similar algorithm:

$$A_{TOTAL} = \sum \left[T_{act} (F) \right]$$

where A_{TOTAL} is the total number of downtime hours for the period. Unlike the first model for determining total PM workload, determining PM downtime does not include the administrative time component or the number of personnel.

Since the design is immature in the validation phase, there is generally more conservative margin in that method, i.e., PM time estimates are usually high. To assign a PM task time, the validation phase PM prediction method incorporates a three point time line for each SPMA/Task, a table of general design features for the SPMA, a set of three decision guidelines for each of the design features, and a seven point scale.

In the full scale development phase, with increased design detail and more visibility, a more detailed prediction method is provided. To assign a PM task time, the FSD phase PM prediction method incorporates a detailed task analysis, a detailed table of elemental task times related to action/design features, and a regression model.

This study does not include a method for determining which tasks must be done. It does, however, offer methods for estimating PM task completion times appropriate in two acquisition phases.

6.2 Validation Phase Product

6.2.1 Overview

In the validation phase, the maintainability engineer needs a method to convert conceptual design features into PM task times. This method requires the engineer to use lists of generalized design features with one list for each SPMA, decision guidelines for weighting effects of each design feature, a range of times (Min, Max, Most likely) for each SPMA/Task pair, and judgement to fit the accumulated weight factors to the time-line. Figure

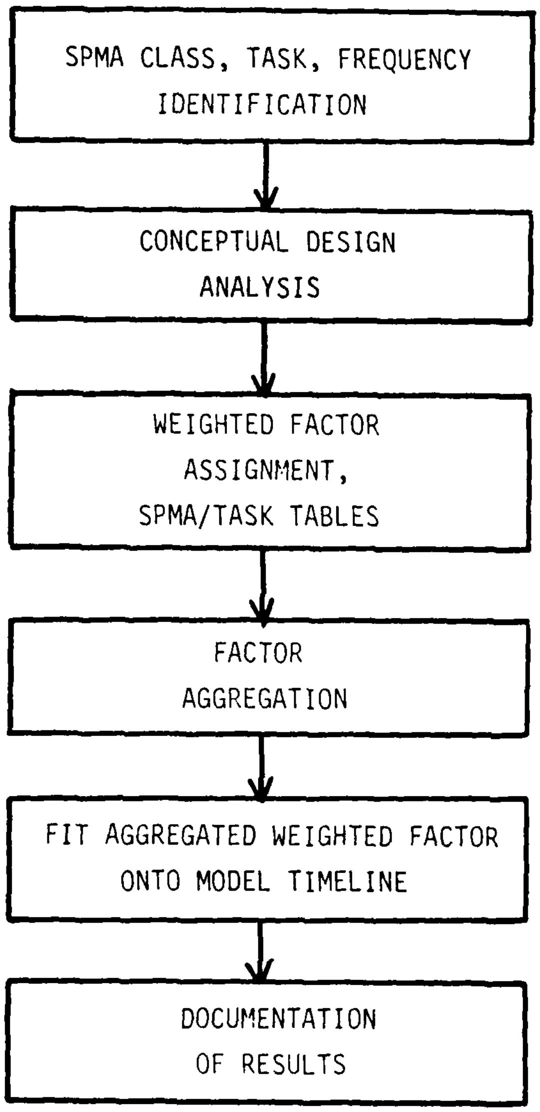


Figure 6.2.1-1 A Process Flow for the VAL Phase PM Prediction

6.2.1-1 illustrates the process flow used by the maintainability engineer during the validation phase.

The maintainability engineer uses other tools, such as Failure Modes Effects Analysis and Reliability Centered Maintenance, to determine which PM tasks are required. After assigning each needed task to a reasonable SPMA/Task pair, he or she does a task analysis to the extent allowed by the design. He or she then uses the selected SPMA Design Feature table and associated guidelines for deciding the proper weighting factor for each design feature. The maintainability engineer then determines the average factor weight and applies the SPMA/Task time line and factor weight to a frequency distribution to determine a reasonable task time.

6.2.2 Process Components

6.2.2.1 SPMA Design Features.

For each of the six SPMA categories, we have identified those general design features which affect the time needed to accomplish a PM task. For each design feature identified, we have established guidelines for the minimum, typical, and maximum effect on task time. The design features are sub-divided into three categories which include physical design features, functional design features, and maintainer/task design features. The Design Factor Tables with the Minimum/Typical/Maximum decision guidelines are presented in Appendix A.

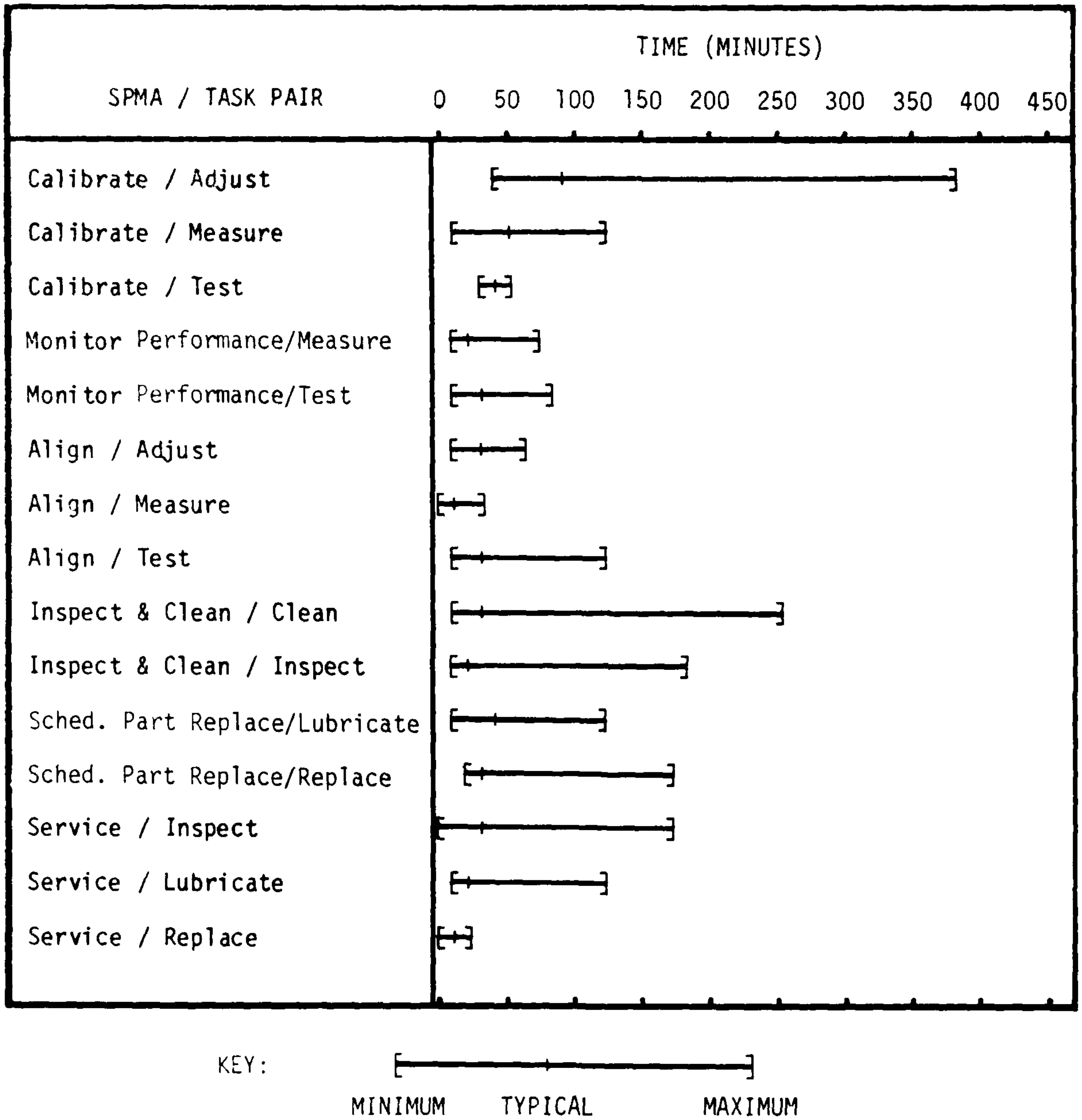


Figure 6.2.2.2-1 Range of SPMA/Task Pair Time Lines

The maintainability engineer must use a degree of judgement to assign factor weights using a seven point scale. The seven point scale was chosen for ease of use, but other rating scales may be substituted. The minimum factor weight is ONE. The typical factor weight is FOUR, and the maximum factor weight is SEVEN. When, however, a design feature does not apply, or when the minimum and typical weight guidelines are the same, he allocates the minimum weight (ONE).

6.2.2.2 SPMA/Task Pair Time Lines

From the matrix of SPMA and generic preventive maintenance tasks presented in Table 6.1.2-3, a list of SPMA/Generic Task pairs was derived. Time-lines for each SPMA/task pair were developed. These SPMA/Task pairs were developed from the data collected and each time line represents the minimum, most likely, and maximum times associated with each task. The typical task completion time is defined as the modal value for each time line value. Figure 6.2.2.2-1 illustrates the range and variation in task completion times among the SPMA/Task pairs. The maintainability engineer uses a distribution curve based upon the SPMA/Task time lines and weighted design feature factors to predict the PM task completion time.

6.2.2.3 Distribution Curve

Figure 6.2.2.3-1 illustrates the distribution curve used in determining individual PM task completion times for the validation phase. The log normal frequency distribution curve is used according to characteristics of preventive maintenance activities set forth in MIL-STD-472. In this study,

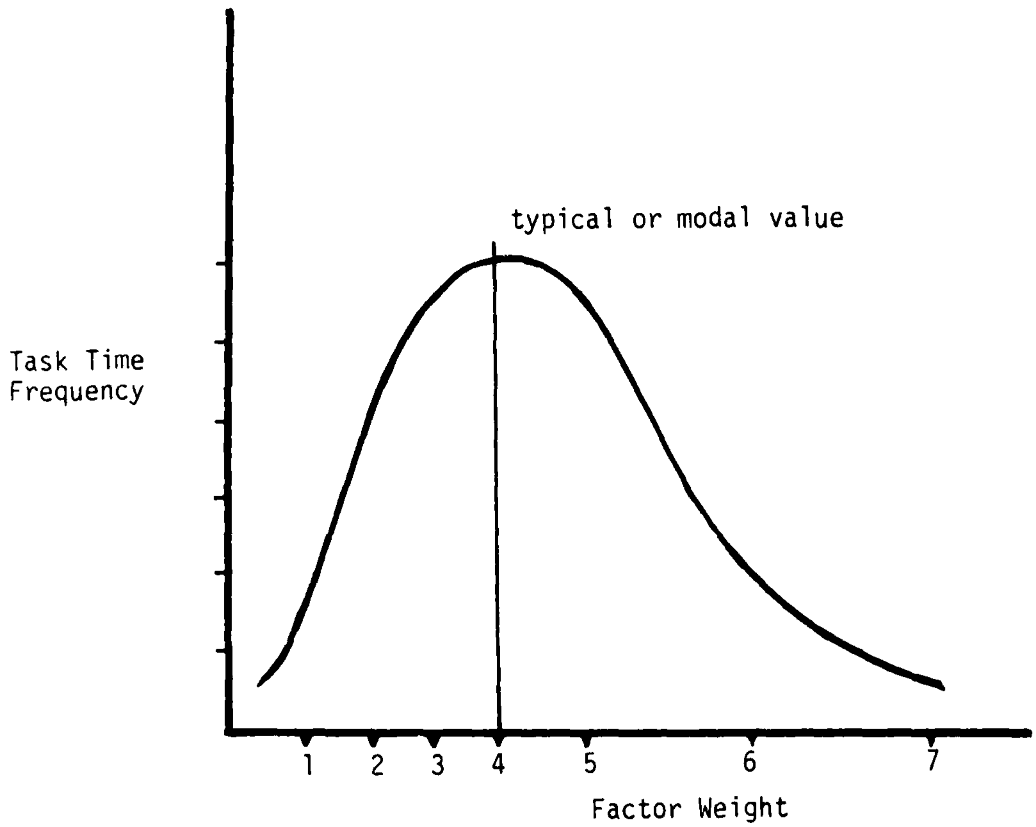


Figure 6.2.2.3-1 Distribution Curve with Assigned Weight Factors

scheduled and preventive maintenance activities typically have standard deviations greater than the arithmetic mean. This implies complex activities containing many possible subactivities. In such cases, according to MIL-STD-472, the tendency is for the applicable distribution to be skewed to the right, and is, therefore, assumed to have log normally distributed completion times. This log normal distribution is representative of the expected population of all maintenance task times. Use of this distribution in combination with an average weighted design feature factor, permits the maintainability engineer to reasonably estimate individual task times with a reasonable margin for error. The seven point weight factors are overlayed onto the distribution curve with the typical weight (four) assigned to the distribution peak or mode and the end weights (one, seven) at approximately the 5% and 95% points. The intermediate weights were located in a manner consistent with the cumulative distribution values.

6.2.3 Example of Validation Phase Product

6.2.3.1 Example System Description

The following paragraph describes a control console subsystem. The maintenance procedures associated with cleaning this subsystem are presented to illustrate how this product is used. The control console of this information processing system contains three equipment bays. Each is a typical electronic rack enclosure with chassis and controls mounted on the front of each rack. For maintainer access, a hinged door is mounted on the back of each rack. The system is used in a typical computer operating area,

with ample room at the back of the console to provide freedom of movement for the maintainer. The maintainer uses a portable vacuum cleaner for cleaning tasks.

6.2.3.2 PM Task Description

The PM Instruction Card for the task reads:

> Inspect and clean the inside of each rack.
> Remove all loose dirt, debris, etc., with vacuum.

This task is to be performed separately for each of three racks in the console, disregarding any attention to the other two racks and to any chassis in it. It does not require cleaning of the exterior surface of the console. The task may be done by the operator or an entry level technician.

6.2.3.3 Task Analysis Using Design Feature Table.

The following steps comprised the task analysis:

1) Determine which SPMA category and which Task type.
   In this example, the maintainability engineer assigned:
   - Inspect and Clean SPMA category
   - Clean Task
2) Assign weights to design feature for selected SPMA.

Figures 6.2.3.3-1, 6.2.3.3-2, and 6.2.3.3-3 show the Inspect and Clean SPMA design features and weights chosen by the engineer. The maintainability

PHYSICAL DESIGN FEATURE DECISION GUIDANCE

DESCRIPTION	MINIMUM			TYPICAL			MAXIMUM
Item Type	Simple Electronic or Mechanical Assembly			Electromechanical or electronic Assembly			Complex Electromechanical Assy
FACTOR	1	2	3	4	5	6	7
Item Size	Hand-held			One Chassis			Multi-rack/chassis
FACTOR	1	2	3	4	5	6	7
Item Function	Single			Small Number of Related Functions			Multifunctional w/ Distributed Processors
FACTOR	1	2	3	4	5	6	7
Item Materials	Durable, No Precautions Required			Somewhat Durable, Some Care Required			Fragile, Extreme Care Required
FACTOR	1	2	3	4	5	6	7
Accessability	Surface			Remove Single Plate			Complex Disassembly
FACTOR	1	2	3	4	5	6	7
Visibility	Unobstructed, Clear			Very Little Obstruction, Limited			Mostly Obstructed, Poor
FACTOR	1	2	3	4	5	6	7
Modularity	Fully			Some			Limited / None
FACTOR	1	2	3	4	5	6	7

Figure 6.2.3.3-1 Inspect and Clean SPMA -- Physical Design Features

FUNCTIONAL DESIGN FEATURE DECISION GUIDANCE

DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Part Type	Simple Mechanical	General Electro - mechanical	Complex Electronic /Mechanical
FACTOR	1 2 3	4 5 6	7
Part Size	Hand-held Easily Handled	One-man Lift Easily Handled	Multi-person, or Mechanical Lift, or Extremely Small and Hard to Handle
FACTOR	1 2 3	4 5 6	7
No of Assoc Parts	None	Ten to Twenty	More than 25
FACTOR	1 2 3	4 5 6	7
Obstructions	None	Few, Easy to Reach Requires No Disassembly	Many or Large Difficult Reach Requires extensive Disassembly
FACTOR	1 2 3	4 5 6	7
Safety Consideration	None	Requires Some Precautions	Requires Extensive Precautions Hazardous
FACTOR	1 2 3	4 5 6	7

Figure 6.2.3.3-2 Inspect and Clean SPMA -- Functional Design Features

MAINTAINER/TASK DESIGN FEATURE DECISION GUIDANCE

DESCRIPTION	MINIMUM			TYPICAL			MAXIMUM
Number of Maintainers	One			One			Two or More
FACTOR	1	2	3	4	5	6	7
Maintainer Skill Level	Entry-level Technician			Specially Trained Tech			Field Engineer
FACTOR	1	2	3	4	5	6	7
Preparation / Set-up	None, or Very Little			Some Equipment Set-up			Multiple Complex Equipment Set-up
FACTOR	1	2	3	4	5	6	7
Cleaning Materials and /or Tools	None			Single Tool, Single Agent			Multiple Tools, Multiple Agents
FACTOR	1	2	3	4	5	6	7
Disposition of Waste	Throw-away Trash			Some Care or Precautions Required			Requires Special Container or Handling
FACTOR	1	2	3	4	5	6	7
Number of Task Steps	Less Than Five			Five to Ten			More Than 25
FACTOR	1	2	3	4	5	6	7
Instructions and Documentation	One Explicit Clear Page or Card			One Manual -- Fairly Clear			Multi-volume Manual, Ambiguous
FACTOR	1	2	3	4	5	6	7
Physical Environment	Lab Workbench			Operating Area Well Lighted Controlled Climate			Cramped. Abnormal Working Conditions or Positions
FACTOR	1	2	3	4	5	6	7

igure 6.2.3.3-3 Inspect and Clean SPMA -- Maintainer/Task Design Features

engineer marked the appropriate weight factors, based on the seven point scale, on the design feature decision guide. In this example, the total of the twenty design feature weights is 48. The average weight factor is 2.4.

6.2.3.4 Fitting Weight Factor Averages to the Distribution

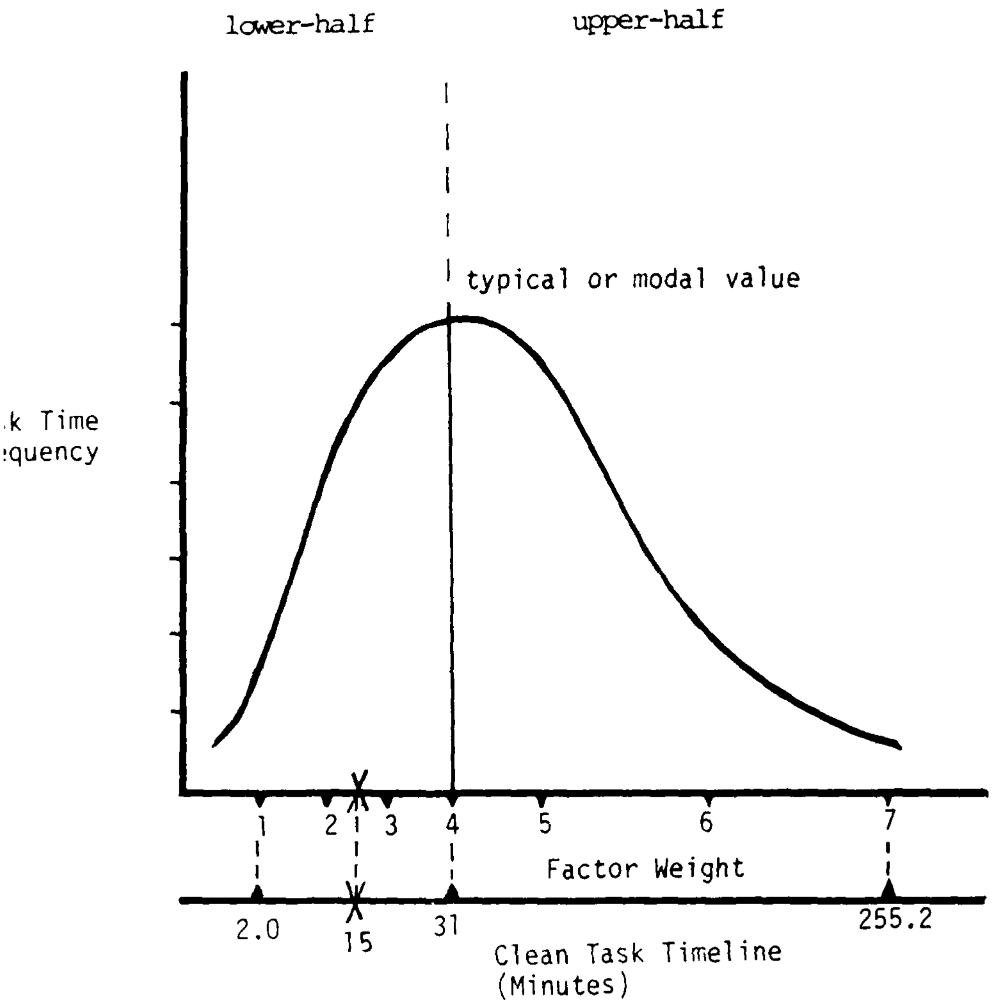
The maintainability engineer finds the range of Clean Task completion times for the Inspect and Clean SPMA in Appendix A. Those times are:

Minimum	2.0 minutes
Typical	31.0 minutes
Maximum	255.2 minutes

These times, with the averaged weight factor determined above are superimposed on the distribution as illustrated in Figure 6.2.3.4-1. The maintainability engineer can determine the task completion time from the graph and by using the following method.

6.2.3.4.1 Deriving Estimates Using the Validation Phase Product

The initial step in deriving a VAL phase prediction requires the user to subjectively rank design features related to the system or equipment, as was indicated in section 6.2.2.3. Once an average factor weight is determined, the maintainability engineer applies the following steps to derive a prediction.



- 2.4, as estimated factor weight, equals about 15 minutes on the overlaid timeline.

Figure 6.2.3.4-1 Fitting Design Feature Weights Onto Curve

lied to other areas of study. The products developed in this study have imited potential. With refined, validated products in which data can be ained from experts, applications of the methodology can be made to a number areas. However, without a validation study to support the use of the hodology and products, its use will most likely remain limited. We are vinced that the methodology will withstand validation, and thus encourage

.2 Revision of PM Procedures for MIL-HDBK-472

MIL-HDBK-472 is currently being revised, incorporating the newest cedures and techniques in maintenance prediction. The products developed this study provide a basis for refining present MIL-HDBK-472 procedures ated to PM.

Consistent with the guidelines being used to develop the new .-HDBK-472, Harris Government Systems has designed two procedures which can used to predict PM parameters. The procedures developed in this study are ısistent with procedures currently in the handbook, where predictions of the lowing can be made:

PM Task Times	Mpmj
Mean PM Times	Mpm
Mean PM Downtimes	MDT pm
Maximum PM Times	Mmaxpm

expert maintainers were found to provide data quickly and inexpensively.

The methods presented in this report, while useful in their present form, should still be refined and validated across a wider range of Air Force PM tasks. With minor refinement, the products developed in this study could become commonly used tools in future preventive maintenance planning and development.

7.3 Research Directions and Applications

7.3.1 Model, Product Validation

A rigorous validation of the subjective estimation methodology would add significantly to the acceptability and applicability of the products. Although the methods used to collect the data in the present study were developed using sound methodology and data were accurately collected, a validation study would give greater credibility to the results. The validation activity would include collection of additional task time and estimated task time data on more equipments similar to those used in this effort. It would also include collection of data on other equipments. Importantly, it should include the tracking of an application of these methods through a design effort.

To reiterate, the validation effort would serve two purposes. First, it would provide insights into strengths and weaknesses of the products as they presently exist and, therefore, results could be used to refine the methodology. Second, once proven valid, the products can be modified and

seful when it is desirable to design a system with the lowest ossible life-cycle maintenance costs. If those design features with high ssociated PM times can be traded off with design features having lower PM ime requirements, system downtime resulting from PM can be significantly educed.

.2 Study Findings

As this study progressed, three of our findings influenced the methods sed to provide the final products. First, we determined that no accurate PM ata base currently exists from which one can extract useful PM task ompletion times. Although maintenance records are kept at all the sites we tudied, the information contained within these records is not sufficiently letailed to permit the extraction of useful time data. In refining our rediction techniques and to improve the quality of the data base, it may be eneficial to update maintenance record keeping procedures. By developing a ore detailed data recording procedure, and by consistently applying it across ommands, data would be more useful for future maintenance manpower lanning. Second, we found that little or no relationship existed between urrent Air Force standard PM task completion times and expert maintainers ime estimates. At some sites, more time was made available for certain tasks han was actually required, while at other sites less time was made vailable. Administrative time was almost universally folded into task ompletion times. Greater efficiency may be achieved if more precise aintenance time allotments are provided. Finally, our results supported the se of expert maintainers as a valid source of preventive maintenance times. ubjective estimation techniques which capitalized on the knowledge base of

7.0. CONCLUSIONS AND RECOMMENDATIONS

7.1. Completion of Study Requirements

The primary objective of this study, to develop a technique for predicting system and equipment preventive/scheduled maintenance downtime and workload as a function of equipment design features, was achieved. Two products were developed in fulfilling this objective. First was a product for making predictions in the validation phase of system or equipment acquisition. This product provides the maintainability engineer a method for determining the approximate PM task completion time required for a system given the limited design information available in the validation phase. Once the maintainability engineer has identified some generalized design features associated with a system or equipment and can make some decisions regarding the weights to be assigned to the design features, he can generate an estimate of PM time necessary for that system. The second product is an analytical procedure which enables the maintainability engineer, armed with a list of task element times differentiated by design features, to easily extract expected PM task completion times from detailed design features. This product has its greatest utility when more detailed design information becomes available and, thus, it is applicable during the Full Scale Development phase of system acquisition.

Consistent with study requirements, the products developed are useful during both early and later phases of an acquisition. In addition to their utility in predicting PM task times, they can be used by the maintainability engineer or system designer in making design tradeoffs. This is particularly

The maintainability engineer, in order to determine active scheduled and preventive maintenance task completion time for an equipment or system would need only to sum up all expected task times for that equipment or system. However, the summed active task time for the FSD model would not account for any administrative time spent.

6.4 Variations in Results

Some discrepancy exists between the predicted task completion times for the two products. In the example, the VAL phase task completion time was estimated at about 15 minutes while the FSD phase time was estimated at about 2 minutes. There are two reasons why a discrepancy is expected between the two methods. First, the VAL phase method includes PM administrative task elements, such as getting test equipment and waiting for equipment warm-up, whereas the FSD method does not include administrative elements. Although a method for predicting administrative task completion time was not derived for the FSD model, the variation in this case may be due to the fact that some minimum administrative time is required even for active tasks very short in duration. Second, the VAL phase method, because of the lack of detailed design information, inherently has more variance because some subjective decisions are made by the maintainability engineer. In the FSD phase method, many more details are known about the design and, therefore, the engineer is able to choose design features and associated task completion times with more precision.

ACTION	DESIGN FEATURE	LINE #	TIME
Open	Cabinet Door, Handle Turns 1/4 Rotation	12.01	4.2 sec
Inspect	Look Inside for Dirt, Debris, Loose Connections	8.18	72.0 sec
Clean	Inside Cabinet Using Vacuum Cleaner with Flex Hose and Plastic Tapered Nozzle	3.46	56.2 sec
Close	Cabinet Door, Handle Turns 1/4 Rotation	4.04	4.2 sec

SUM = 136.6 sec

APPLY MODEL

$$T_{pm} = \text{antilog}\,[(1.03)\log(136.6) - 0.12]$$

$$T_{pm} = \text{antilog}\left[(1.03)(2.135) - 0.12\right] = 119.96 \text{ sec}$$

MEASURED TIME = 120 sec

Figure 6.3.3.3-1 FSD Prediction Process

1) determine which actions or task elements must be done to complete the PM task
2) determine the design feature details for that PM task (number and type of fasteners, type and location of adjustments, test instruments and tools needed, etc.),
3) assign task element estimated completion time from the table in Appendix B,
4) sum the estimated times for all task elements.

Figure 6.3.3.3-1 illustrates this process for our example.

6.3.3.4 Determining Expected Actual PM Task Completion Times

From this example, the sum of task element time factors ($T_{estimated}$) is 136.6 seconds. $T_{estimated}$ is inserted into the prediction algorithm to determine the expected actual PM task completion time:

$$T_{expected\ actual} = \text{antilog}\ [(1.03)\log(\sum T_{estimated}) - 0.12]$$

$$T_{expected\ actual} = \text{antilog}\ [(1.03)\log(136.6) - 0.12]$$

$$T_{expected\ actual} = \text{antilog}\ [(1.03)(2.135) - 0.12]$$

$$T_{expected\ actual} = 119.96 \text{ seconds}$$

Therefore, the expected actual time to complete the example task is approximately two minutes.

controls are mounted in the front of each typical rack enclosure. Access to the back is through a hinged door. Each door is fastened by a quarter-turn "L" shaped handle. The maintainer has use of a portable vacuum cleaner.

6.3.3.2 PM Task Description

The PM Instruction Card reads:

> Inspect and clean the inside of each rack.
> Remove all loose dirt, debris, etc., with vacuum.

This task is to be performed separately for each of three racks in the console, disregarding any attention to the other two racks and to any of the chassis in it. It does not require cleaning of the exterior surface of the console. The task may be done by the operator or an entry level technician.

6.3.3.3 Task Analysis Using Task Element Table.

This task analysis is similar to the analysis used for corrective maintenance, as in MIL-HDBK-472 prediction methods. In this analysis, the maintainability engineer identifies design feature details and assigns the task elements defined by the type of PM performed. The analysis is comprised of the following steps:

6.3.2 Process Components

6.3.2.1 Task Element Tables

The Task Element Tables, in Appendix B, provide an ordered summary of task element time factors. The table is ordered by key action word for the task element. Should the maintainability engineer determine that task elements are needed which are not listed in the table, he may use judgement or collect data using the subjective estimation method to establish a time factor. The time factors are not time standards, but if time standards should become available, they may be used with the table.

6.3.2.2 The Model

The algorithm provides a reasonably accurate and definitely useful prediction of PM task times when detailed design features are known. The sum of the task element time factors($T_{estimated}$) is the only variable to be determined through task analysis. The prediction algorithm is:

$$T_{actual} = \text{antilog} \left[1.03 \left(\sum T_{estimated}\right) - 0.12\right]$$

6.3.3 Example of Full Scale Development Phase Product

6.3.3.1 Example System Description

The previous example of the control console is described again in reference to this prediction method. To reiterate, the console chassis and

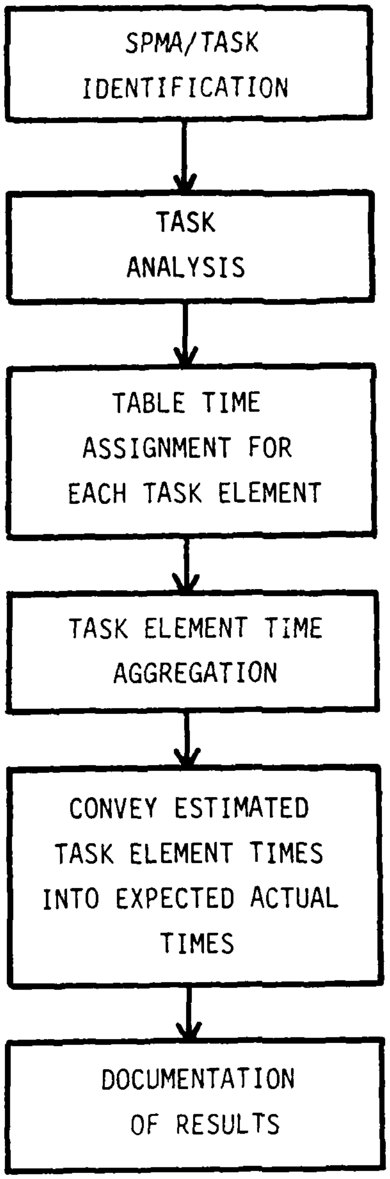


Figure 6.3.1-1 A Process Flow for the FSD Phase PM Prediction

6.3 Full Scale Development Phase Product

6.3.1 Overview.

In the Full Scale Development phase, the maintainability engineer needs a conservative method to convert evolving detailed design features into active PM task times. This method uses lists of task element times differentiated bydesign features, a mathematical model, and expert judgement to fill any gaps in the task element list. Figure 6.3.1-1 illustrates the process flow followed by the maintainability engineer in using this product.

As with the validation phase product, the maintainability engineer uses other tools, such as failure Mode Effects Analysis, to determine which PM tasks are required. After defining the tasks needed, he or she performs a task analysis to the extent allowed by the design. Then, to apply the product, he or she identifies each task element needed to accomplish the PM task, assigns a time factor from the task element table, adds the individual time factors, and finally applies the summed time factors to the model to find the active task time. Because greater system definition is available in the FSD Model, the FSD product is useful in developing more accurate predictions of active task completion time. Although not developed in this study, accurate administrative task completion times could be derived using the same subjective estimation techniques. However, such estimates would probably have to be derived on a case by case basis due to variability in maintenance procedures and work area layouts.

In this example with 2.4 as the estimated factor weight for the Inspect and Clean SPMA, the estimated task completion time is 15.54 minutes.

If the estimated factor weight had fallen in the upper half of the distribution, a slightly different process is required. In this case, subtract 4 (the typical scale value) from the estimated factor weight (e.g. 6.4) then multiply the difference by the upper half interval value (74.73).

$$(6.4 - 4)\ (74.73) = 2.4\ (74.73) = 179.36$$

3) Add this product to the typical value (31) to obtain the estimate

$$179.36 + 31 = 210.36$$

Given an estimated factor weight of 6.4, the estimated PM task time for Inspect and Clean SPMA would be 210.36 minutes.

If, however, the user wants only a rough estimate of the PM task completion time, he or she could merely place the estimated factor weight on the graph along with the known time values and interpolate. As illustrated in figure 6.2.3.4-1, the estimated factor weight (2.4) was placed on the graph and a line was drawn vertically to the time line. In this case, the user would guess that the vertical line falls approximately half way between the minimum value (2.0) and the typical value (31) and would estimate the PM task completion time to be about 14.5 minutes.

value (255.2) and again divide by the number of intervals (3). The time value corresponding to the upper half would be:

$$(255.2 - 31) / 3 = 74.73$$

To obtain the time values corresponding to 5 and 6, simply add this value to the typical value (31) once to obtain the time associated with 5 and twice for the time associated with 6, i.e.:

$$74.73 + 31 = 105.73 \quad \text{(time assoc. with 5)}$$

$$74.73 + 74.73 + 31 = 180.46 \quad \text{(time assoc. with 6)}$$

When these values are placed the time line, the maintainability engineer can make a reasonable estimation by interpolation. However, a more precise estimate of a PM task completion time requires the following steps:

(1) if the estimated factor weight (in this example 2.4) is in the lower half of the distribution, subtract 1 (the minimum scale value) from the factor weight, then multiply the difference by the lower half interval value (in this example 9.67):

$$(2.4 - 1)(9.67) = (1.4)(9.67) = 13.54$$

2) Add this product (13.54) to the time associated with the minimum time value (2.0) to obtain the estimate:

$$13.54 + 2.0 = 15.54 \text{ minutes}$$

First, the minimum, typical, and maximum task times are placed on the graph (see Figure 6.2.3.4-1). From the Inspect and Clean SPMA example, the scale value 1 (minimum) is assigned 2.0 minutes, scale value 4 (typical) is assigned 31.0 minutes, and scale value 7 (maximum) is assigned 255.2 minutes. Second, although not necessary for deriving a prediction, the maintainability engineer can calculate time values for the remaining points on the scale. In either case, the scale is divided into two halves, the lower and the upper half, as illustrated in Figure 6.2.3.4-1. The scale is divided in this way due to the fact that the distribution is skewed, but intervals on each side of the mode are roughly equivalent. Determining the remaining scale values is accomplished similarly for both halves of the distribution. For the lower half (scale values 1-4) subtract the minimum value (2.0 in this example) from the typical value (31 in this example). The resulting value (29) is then divided by the number of intervals (in this case 3) to obtain the time in minutes that makes up each interval in the lower half of the distribution.

$$(31-2) / 3 = 9.67$$

Times associated with scale values 2 and 3 can then be calculated by adding this value to the minimum value (once for 2 and twice for 3). In this example, the time associated with scale value 2 is 2.0 + 9.67 = 11.67. Similarly, the time associated with scale value 3 is 2.0 + 9.67 + 9.67 = 21.34. If it were added a third time, the time associated with scale value 4 would result (31).

To calculate the time values for the upper half of the distribution, a similar process is used. Subtract the typical value (31) from the maximum

Based on this, we feel a need to assess the suitability of these procedures for inclusion in the next version of MIL-HDBK-472.

7.3.3 Expert Rule-Based Systems for Preventive Maintenance

Recent advances in artificial intelligence, or computer systems that simulate intelligent behavior and emulate human experts, have made this area popular in recent times. A viable application of that technology exists in the area of maintainability design. It is now feasible that such a system could incorporate maintainability design rules to aid engineers in quickly and efficiently designing systems or equipments with cognizance of effective maintainability design. Maintenance experts' knowledge could be incorporated into an intelligent system's data base and exploited for future system or equipment design. The subjective estimation techniques presented in this study may provide an expedient means of obtaining necessary data for inclusion into such a rule-based system.

Intelligent or expert rule-based systems apply rules or logical judgements to a set of data, record the consequences of the application, and then alter the rules or make inferences based upon the previous situation. These systems are currently used to solve problems in specialized areas, such as medical diagnosis and mineral exploration. Computer programs used in expert rule-based systems differ from conventional programs because their tasks have no algorithimic solutions and, often must form solutions based upon incomplete information.

In building an expert system, the following prerequisites must be considered: 1) at least one human expert must be available to provide special knowledge, judgement, and experience on a series of tasks to the system: 2) a man-machine interface must exist which allows the expert to explain task methodology to the system; and, 3) the task must have a well bounded domain of application. As noted in this study, there is a large pool of expert maintainers available to generate the maintainability data base and to assist the maintainability engineer during the development of a system. Subjective estimation techniques can be applied to build this expert data base for inclusion into a rule-based system.

The major advantage of a rule-based system for predicting preventive maintenance manhours as a function of system or equipment design, is that a maintainability engineer can quickly determine the impact of various designs on maintenance task completion times. Therefore, he or she can impact the design early when the immediate cost impact of design enhancements is lowest.

7.3.3.1 Rule-Based Systems and Logistic Support Analysis

Currently, Logistics Support Analysis Records (LSAR), via special input forms, identify PM task functions which denote specific maintenance, operator, or supporting functions for a system or equipment. Because of this, the LSAR should be considered as a source and vehicle for inputting PM data into a rule-based system if one is developed.

The LSAR process could be used by a maintainability engineer to build and modify PM task descriptions. Task descriptions and times could be derived from expert maintainers. Using such an interactive rule-based system, the engineer could select task element narratives, modify the narratives with new parameter requests, and thus define the maintenance task. Using the engineer's responses to requested parameters, the rule-based system would define the tools, supplies, and support items needed, assign element times, and generate personnel and support requirements. When the maintenance function is fully defined, the system would combine the times, tasks, and support resources needed, and generate a combined estimate for personnel and support requirements.

The basic method for predicting PM task completion time as a function of design characteristics would not be altered using LSAR and a rule-based system, but instead greatly simplify use of the method. It could also reduce logistics support costs in system procurements.

In the early phases of the system acquisition, the maintainability engineer defines the maintenance concept, designs a number of maintenance scenarios, and establishes preliminary maintenance tasks. During the Validation Phase, the maintainability engineer could use the interactive rule-based system to apply the product developed in this study to establish the scheduled maintenance tasks, and to capture the probable support requirements.

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APPENDIX A

VALIDATION PHASE PM PREDICTION TABLES

TABLE	CONTENTS
A	SPMA Categories /Generic PM Task Types
B	Definitions of SPMA and Generic Tasks
C	Design Factor Classes Affecting CALIBRATE SPMA
D	Design Factor Classes Affecting MONITOR PERFORMANCE SPMA
E	Design Factor Classes Affecting ALIGN SPMA
F	Design Factor Classes Affecting REPLACE PARTS (SCHEDULED) SPMA
G	Design Factor Classes Affecting INSPECT AND CLEAN SPMA
H	Design Factor Classes Affecting SERVICE SPMA

TABLE A SPMA CATEGORIES / GENERIC PM TASK TYPES

Time In Min * = No Data Best Estimate GENERIC TASK		SPMA CATEGORY					
		CALI - BRATE	MONITOR PERFORM	ALIGN	INSPECT AND CLEAN	REPLACE PARTS SCHEDULED	SERVICE
ADJUST TASK	TYP MIN MAX	84.5 45.0 380.0		30 15 * 60			
CLEAN TASK	TYP MIN MAX				31.0 2.0 255.2		
INSPECT TASK	TYP MIN MAX		16.2 7.1 66.0		18.0 2.8 180.0		24.6 0.1 170.0
LUBRICATE TASK	TYP MIN MAX					30 5 * 120	12.8 5.0 119.0
MEASURE TASK	TYP MIN MAX	48.7 9.2 120	10.6 3.1 47.0	1.1 0.1 16.0			
REPLACE TASK	TYP MIN MAX					30 15 * 180	3.1 2.2 9.5
TEST TASK	TYP MIN MAX	37.5 33.5 45.	22.2 4.0 75.0	30 5 * 120			

TABLE B DEFINITIONS OF SPMA AND GENERIC TASKS

1 SPMA CATAGORIES

CALIBRATE	Transfer Measurement Standards to Precision Measuring Equipment, Built-In-Test Circuits, Built-in-test Equipment, and to some Metered Tools. Usually a function of a PME Lab but may be a task for complex systems maintainers.
MONITOR PERFORMANCE	Inspect, Test, or Measure to Determine Item Compliance with expected standard characteristics. Usually done to Detect Incipient Failure.
ALIGN	Adjust parameters to more desirable values though measured values are not outside range of specified acceptable conditions.
INSPECTION & CLEANING	Removal of dirt, corrosion, residue, etc., which might cause unwarranted deterioration of operation.
REPLACE PART (SCHEDULED)	Replacement of a serviceable item with a new item,based only on the completion of a specified number of hours, days, miles, rounds, etc.
SERVICE	Replace, or Restore to Desired Level, Consumables such as Coolant, Charts, Hydraulic Fluid, Rolls of Paper, etc. For this study, includes Application of Lubricants(Grease, Oil, etc.).

2 GENERIC PM TASKS

ADJUST	Bring to Specified Position or to More Satisfactory State.
CLEAN	Wash, Scrub, Remove Residue, Rinse, Dry etc.
INSPECT	Do Critical Observation, Look, Listen or Feel For Specific Conditions, Evaluate Wear, etc.
LUBRICATE	Apply Lubricant on or in specified places.
MEASURE	Determine Dimensions, Capacity, Amount, levels or shapes.
REPLACE	Restore to Former Place or Position or Substitute Servicable Item for Like Item That Is Damaged, Worn Out, or Malfunctions.
TEST	Verify Operational Readiness by Doing Specified Operations.

TABLE C   DESIGN FACTOR CLASSES AFFECTING CALIBRATE SPMA

Calibrate Transfer Measurement Standards to Precision Measuring Equipment, Built-In-Test Circuits, Built-in-test Equipment, and to some Metered Tools.

Usually a function of a PME Lab but may be a task for complex systems maintainers.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Physical Design Features	Item Type	Simple Electronic or Mechanical Assembly	Electromechanical or electronic Assembly	Complex Electromechanical Assy
	Item Size	Hand-held	One Chassis	Multi-rack/chassis
	Item Function	Single	Small Number of Related Functions	Multifunctional w/ Distributed Processors
	Accessability	Surface	Remove Single Plate	Complex Disassembly
	Connecter Type	Surface, Friction	Quarter-turn Connectors	Mechanical / Solder Connections
	Modularity	Fully	Some	Limited / None
Functional Design Features	Warm-up / Stabilization	None	Fifteen to Thirty Minutes	More Than Six Hours
	BIT Features / Testability	Self-Indicating, Fully Automated	Some BIT	None
	Control Location	Outside Panel	Some Located Internally	Most Located Internally
	Control Type	Discrete Step or Less Than One Full Turn	Discrete or Continuous Multi-turn	Multiple Controls Required for Each Step
	Meter / Indicator Location	Outside Panel	Some Internal No Obstruction	Mostly Internal Some Obstruction
	Meter / Indicator Type	"Idiot" Lamp	Common Panel Meter	Complex Guages
		1 2	3 4 5	6 7

TABLE C DESIGN FACTOR CLASSES AFFECTING CALIBRATE SPMA (CONTINUED)

Calibrate Transfer Measurement Standards to Precision Measuring Equipment, Built-In-Test Circuits, Built-in-test Equipment, and to some Metered Tools. Usually a function of a PME Lab but may be a task for complex systems maintainers.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Maintainer /Task Design Features	Number of Maintainers	One	One	Two or More
	Maintainer Skill Level	Entry-level Technician	Specially Trained Tech	Field Engineer
	Preparation / Set-up	None, or Very Little	Some Equipment Set-up	Multiple Complex Equipment Set-up
	Cleaning Materials / Tools	None	Single Tool, Single Agent	Multiple Tools, Multiple Agents
	Disposition of Waste	Throw-away Trash	Some Care or Precautions Required	Requires Special Container or Handling
	Number of Task Steps	Less Than Five	Five to Ten	More Than twenty-five
	Measurement Granularity	GO / NOGO	Coarse	Fine, Precise
	Measurement Sensitivity	Not Critical	Low Chance of Error	High Chance of Error
	Instructions and Documentation	One Explicit Clear Page or Card	One Manual -- Fairly Clear	Multi-volume Manual, Ambiguous
	Physical Environment	ATE Worksite	Lab Workbench	Mobile or Remote

1 2 3 4 5 6 7

TABLE D DESIGN FACTOR CLASSES AFFECTING MONITOR PERFORMANCE SPMA

Monitor Performance Inspect, Test, or Measure to determine item compliance with expected standard characteristics. Usually done to detect incipient failure.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Physical Design Features	Item Type	Simple Electronic or Mechanical Assembly	Electromechanical or electronic Assembly	Complex Electromechanical Assy
	Item Size	Hand-held	One Chassis	Multi-rack/chassis
	Item Function	Single	Small Number of Related Functions	Multifunctional w/ Distributed Processors
	Accessability	Surface	Remove Single Plate	Complex Disassembly
	Visibility	Unobstructed, Clear	Very Little Obstruction, Limited	Mostly Obstructed, Poor
	Connecter Type	Surface, Friction	Quarter-turn Connectors	Mechanical / Solder Connections
	Modularity	Fully	Some	Limited / None
Functional Design Features	BIT Features / Testability	Fully Automated, Self-Indicating	Some BIT	None
	Control Location	Outside Panel	Some Located Internally	Most Located Internally
	Control Type	Discrete Step or Less Than One Full Turn	Discrete or Continuous Multi-turn	Multiple Controls Required for Each Step
	Meter / Indicator Location	Outside Panel	Some Internal No Obstruction	Mostly Internal Some Obstruction
	Meter / Indicator Type	"Idiot" Lamp	Common Panel Meter	Complex Guages

1 2 3 4 5 6 7

TABLE D DESIGN FACTOR CLASSES AFFECTING MONITOR PERFORMANCE SPMA (CONTINUED)

Monitor Performance Inspect, Test, or Measure to determine item compliance with expected standard characteristics. Usually done to detect incipient failure.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Maintainer /Task Design Features	Number of Maintainers	One	One	Two or More
	Maintainer Skill Level	Entry-level Technician	Specially Trained Tech	Field Engineer
	Preparation / Set-up	None, or Very Little	Some Equipment Set-up	Multiple Complex Equipment Set-up
	Number of Task Steps	Less Than Five	Five to Ten	More Than twenty-five
	Measurement Granularity	GO / NOGO	Coarse	Fine, Precise
	Instructions and Documentation	One Explicit Clear Page or Card	One Manual -- Fairly Clear	Multi-volume Manual, Ambiguous
	Physical Environment	Lab Workbench	Operating Area Well Lighted Controlled Climate	Cramped. Abnormal Working Conditions or Positions

1 2 3 4 5 6 7

Align Adjust parameters to more desirable values though measured values are not outside range of specified acceptable conditions.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Physical Design Features	Item Type	Simple Electronic or Mechanical Assembly	Electromechanical or electronic Assembly	Complex Electro-mechanical Assy
	Item Size	Hand-held	One Chassis	Multi-rack/chassis
	Item Function	Single	Small Number of Related Functions	Multifunctional w/ Distributed Processors
	Accessability	Surface	Remove Single Plate	Complex Disassembly
	Visibility	Unobstructed, Clear	Very Little Obstruction, Limited	Mostly Obstructed, Poor
	Connecter Type	Surface, Friction	Quarter-turn Connectors	Mechanical / Solder Connections
	Modularity	Fully	Some	Limited / None
Functional Design Features	Warm-up / Stabilization	None	Fifteen to Thirty Minutes	More Than Six Hours
	BIT Features / Testability	Self-Indicating, Fully Automated	Some BIT	None
	Control Location	Outside Panel	Some Located Internally	Most Located Internally
	Control Type	Discrete Step or Less Than One Full Turn	Discrete or Continuous Multi-turn	Multiple Controls Required for Each Step
		1 2	3 4 5	6 7

TABLE E DESIGN FACTOR CLASSES AFFECTING ALIGN SPMA (CONTINUED)

Align Adjust parameters to more desirable values though measured values are not outside range of specified acceptable conditions.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Functional Design Features	Meter / Indicator Location	Outside Panel	Some Internal No Obstruction	Mostly Internal Some Obstruction
	Meter / Indicator Type	"Idiot" Lamp	Common Panel Meter	Complex Guages
Maintainer /Task Design Features	Number of Maintainers	One	One	Two or More
	Maintainer Skill Level	Entry-level Technician	Specially Trained Tech	Field Engineer
	Preparation / Set-up	None, or Very Little	Some Equipment Set-up	Multiple Complex Equipment Set-up
	Number of Task Steps	Less Than Five	Five to Ten	More Than twenty-five
	Measurement Granularity	GO / NOGO	Coarse	Fine, Precise
	Measurement Sensitivity	Not Critical	Low Chance of Error	High Chance of Error
	Instructions and Documentation	One Explicit Clear Page or Card	One Manual -- Fairly Clear	Multi-volume Manual, Ambiguous
	Physical Environment	Lab Workbench	Operating Area Well Lighted Controlled Climate	Cramped. Abnormal Working Conditions or Positions

1 2 3 4 5 6 7

Replace Parts--Scheduled Replace a serviceable part with a new part,based only on the completion of a specified number of hours, days, miles, rounds, etc.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Physical Design Features	Item Type	Simple Electronic or Mechanical Assembly	Electromechanical or electronic Assembly	Complex Electromechanical Assy
	Item Size	Hand-held	One Chassis	Multi-rack/chassis
	Item Function	Single	Small Number of Related Functions	Multifunctional w/ Distributed Processors
	Accessability	Surface	Remove Single Plate	Complex Disassembly
	Visibility	Unobstructed, Clear	Very Little Obstruction, Limited	Mostly Obstructed, Poor
	Connecter Type	Surface, Friction	Quarter-turn Connectors	Mechanical / Solder Connections
	Modularity	Fully	Some	Limited / None
Functional Design Features	Part Type	Simple Mechanical	General Electro - mechanical	Complex Electronic / Mechanical
	Part Size	Hand-held Easily Handled	One-man Lift Easily Handled	Multi-person, or Mechanical Lift, or Extremely Small and Hard to Handle
	Number of Associated Parts	None	Ten to Twenty	More than twenty-five
	Obstructions	None	Few, Easy to Reach No Disassembly Required	Many or Large Difficult Reach Disassembly Required

1 2 3 4 5 6 7

TABLE F DESIGN FACTOR CLASSES AFFECTING REPLACE PARTS(SCHEDULED) SPMA (CONTINUED)

Replace Parts--Scheduled Replace a serviceable part with a new part, based only on the completion of a specified number of hours, days, miles, rounds, etc.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Functional Design Features	Disposition of Item Replaced	Throw-away Trash	Save / Repair at Next Level	Requires Special Container or Handling
Maintainer /Task Design Features	Number of Maintainers	One	One	Two or More
	Maintainer Skill Level	Entry-level Technician	Specially Trained Tech	Field Engineer
	Preparation / Set-up	None, or Very Little	Some Equipment Set-up	Multiple Complex Equipment Set-up
	Number of Task Steps	Less Than Five	Five to Ten	More Than twenty-five
	Measurement Granularity	GO / NOGO	Coarse	Fine, Precise
	Measurement Sensitivity	Not Critical	Low Chance of Error	High Chance of Error
	Instructions and Documentation	One Explicit Clear Page or Card	One Manual -- Fairly Clear	Multi-volume Manual, Ambiguous
	Physical Environment	Lab Workbench	Operating Area Well Lighted Controlled Climate	Cramped. Abnormal Working Conditions or Positions

1 2 3 4 5 6 7

TABLE 6 DESIGN FACTOR CLASSES AFFECTING INSPECT AND CLEAN SPMA

Inspection & Cleaning Removal of dirt, corrosion, residue, etc., which might cause unwarranted deterioration of operation.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Physical Design Features	Item Type	Simple Electronic or Mechanical Assembly	Electromechanical or electronic Assembly	Complex Electromechanical Assy
	Item Size	Hand-held	One Chassis	Multi-rack/chassis
	Item Function	Single	Small Number of Related Functions	Multifunctional w/ Distributed Processors
	Item Materials	Durable, No Precautions Required	Somewhat Durable, Some Care Required	Fragile, Extreme Care Required
	Accessability	Surface	Remove Single Plate	Complex Disassembly
	Visibility	Unobstructed, Clear	Very Little Obstruction, Limited	Mostly Obstructed, Poor
	Modularity	Fully	Some	Limited / None
Functional Design Features	Part Type	Simple Mechanical	General Electro - mechanical	Complex Electronic / Mechanical
	Part Size	Hand-held Easily Handled	One-man Lift Easily Handled	Multi-person, or Mechanical Lift, or Extremely Small and Hard to Handle
	Number of Associated Parts	None	Ten to Twenty	More than twenty-five

1 2 3 4 5 6 7

TABLE G DESIGN FACTOR CLASSES AFFECTING INSPECT AND CLEAN SPMA (CONTINUED)

Inspection & Cleaning Removal of dirt, corrosion, residue, etc., which might cause unwarranted deterioration of operation.

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Functional Design Features	Obstructions	None	Few, Easy to Reach No Disassembly Required	Many or Large Difficult Reach Disassembly Required
	Safety Considerations	None	Requires Some Precautions	Extensive Precautions Required, Hazardous
Maintainer /Task Design Features	Number of Maintainers	One	One	Two or More
	Maintainer Skill Level	Entry-level Technician	Specially Trained Tech	Field Engineer
	Preparation / Set-up	None, or Very Little	Some Equipment Set-up	Multiple Complex Equipment Set-up
	Cleaning Materials / Tools	None	Single Tool, Single Agent	Multiple Tools, Multiple Agents
	Disposition of Waste	Throw-away Trash	Some Care or Precautions Required	Requires Special Container or Handling
	Number of Task Steps	Less Than Five	Five to Ten	More Than twenty-five
	Instructions and Documentation	One Explicit Clear Page or Card	One Manual -- Fairly Clear	Multi-volume Manual, Ambiguous
	Physical Environment	Lab Workbench	Operating Area Well Lighted Controlled Climate	Cramped. Abnormal Working Conditions or Positions

1 2 3 4 5 6 7

TABLE H DESIGN FACTOR CLASSES AFFECTING SERVICE SPMA

Service Replace, or Restore to Desired Level, Consumables such as Coolant, Hydraulic Fluid, Charts, Rolls of Paper, etc. Includes application of Lubricants (Grease, Oil, etc.).

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Physical Design Features	Item Type	Simple Electronic or Mechanical Assembly	Electromechanical or electronic Assembly	Complex Electromechanical Assy
	Item Size	Hand-held	One Chassis	Multi-rack/chassis
	Item Function	Single	Small Number of Related Functions	Multifunctional w/ Distributed Processors
	Accessability	Surface	Remove Single Plate	Complex Disassembly
	Visibility	Unobstructed, Clear	Very Little Obstruction, Limited	Mostly Obstructed, Poor
Functional Design Features	Consumable Type	Dry / Modular Easy to Handle	Wet or Dry, Some Care in Handling Req'd	Wet or Dry or Gas Special Handling Required
	Consumable Size	Hand-held Easily Handled	One-man Lift Easily Handled	Multi-person, or Mechanical Lift Hard to Handle
	Consumable Amount	1/32 cu ft	1/8 cu ft	More than 1 cu ft
	Obstructions	None	Few, Easy to Reach No Disassembly Required	Many or Large Difficult Reach Disassembly Required
	Safety Considerations	None	Requires Some Precautions	Extensive Precautions Required, Hazardous

1 2 3 4 5 6 7

TABLE H DESIGN FACTOR CLASSES AFFECTING SERVICE SPMA (CONTINUED)

Service Replace, or Restore to Desired Level, Consumables such as Coolant, Hydraulic Fluid, Charts, Rolls of Paper, etc. Includes application of Lubricants (Grease, Oil, etc.).

TYPE	DESCRIPTION	MINIMUM	TYPICAL	MAXIMUM
Maintainer /Task Design Features	Number of Maintainers	One	One	Two or More
	Maintainer Skill Level	Entry-level Technician	Specially Trained Tech	Field Engineer
	Preparation / Set-up	None, or Very Little	Some Equipment Set-up	Multiple Complex Equipment Set-up
	Cleaning Materials / Tools	None	Single Tool, Single Agent	Multiple Tools, Multiple Agents
	Number of Task Steps	Less Than Five	Five to Ten	More Than twenty-five
	Instructions and Documentation	One Explicit Clear Page or Card	One Manual -- Fairly Clear	Multi-volume Manual, Ambiguous
	Physical Environment	Lab Workbench	Operating Area Well Lighted Controlled Climate	Cramped. Abnormal Working Conditions or Positions

1 2 3 4 5 6 7

APPENDIX B

FULL SCALE DEVELOPMENT PHASE PM PREDICTION TABLES

DESIGN FEATURE TABLE

SEQUENCE	MAJOR VERB	SEQUENCE RANGE	
1.0	Adjust	1.1	1.12
2.0	Apply	2.1	2.8
3.0	Clean	3.1	3.67
4.0	Close	4.1	4.4
5.0	Connect	5.1	5.12
6.0	Degauss	6.1	6.4
7.0	Dry	7.1	7.5
8.0	Inspect	8.1	8.31
9.0	Loosen	9.1	9.15
10.0	Measure	10.1	10.11
11.0	Move	11.1	11.13
12.0	Open	12.1	12.7
13.0	Place	13.1	13.74
14.0	Release	14.1	14.5
15.0	Remove	15.1	15.76
16.0	Rinse	16.1	16.1
17.0	Set	17.1	17.20
18.0	Test	18.1	18.3
19.0	Tighten	19.1	19.35
20.0	Type	20.1	20.1

DESIGN FEATURE TABLE

ACTION		DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
1.0	ADJUST: PARTS OR KNOBS FOR DESIRED OUTPUT.		
1.1		DRIVE MOTOR ASSEMBLY (SLIDES IN BRACKET) SO THAT SLACK IS REMOVED FROM DRIVE MOTOR CHAIN.	5.8
1.2		SCREW ON FRONT PANEL FOR REQUIRED ANALOG METER DISPLAY.	7.5
1.3		SCREW ON FRONT PANEL TO TUNE INSTRUMENT TO INPUT SIGNAL.	6.6
1.4		SCREW ON REAR PANEL FOR REQUIRED OSCILLOSCOPE/ANALOG METER DISPLAY.	9.6
1.5		VARIABLE RESISTOR OR CAPACITOR ON THE EDGE OF AN EXPOSED CIRCUIT CARD FOR A REQUIRED WAVEFORM/VOLTAGE.	9.2
1.6		VARIABLE RESISTOR OR CAPACITOR IN THE CENTER OF AN INTERNAL CIRCUIT CARD FOR A REQUIRED WAVEFORM/VOLTAGE.	8.4
1.7		TWO VARIABLE RESISTORS OR CAPACITORS IN THE CENTER OF AN EXPOSED CIRCUIT CARD FOR A REQUIRED WAVEFORM/VOLTAGE.	10.4
1.8		VARIABLE RESISTOR OR CAPACITOR ON THE EDGE OF AN INTERNAL CIRCUIT CARD FOR A REQUIRED WAVEFORM/VOLTAGE.	12.0
1.9		TWO VARIABLE RESISTORS OR CAPACITORS ON THE EDGE OF AN INTERNAL CIRCUIT CARD FOR A REQUIRED WAVEFORM/VOLTAGE.	12.0
1.10		THREE VARIABLE RESISTORS OR CAPACITORS ON THE EDGE OF AN INTERNAL CIRCUIT CARD FOR A REQUIRED WAVEFORM/VOLTAGE.	24.5
1.11		VARIABLE RESISTOR ON THE EDGE OF AN INTERNAL CIRCUIT CARD TO OBTAIN A SYSTEM FAULT.	5.2
1.12		VARIABLE RESISTOR ON THE EDGE OF AN INTERNAL CIRCUIT CARD TO OBTAIN PROPER SYSTEM OPERATION.	6.7

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
2.0 APPLY: SUBSTANCE TO EQUIPMENT/TOOL SURFACE.		
2.1	ISOPROPYL ALCHOHOL TO COTTON SWAB DIPPING SWAB IN SOLUTION.	1.9
2.2	OIL TO BEARING WITH STANDARD OIL GUN-TYPE APPLICATOR.	16.4
2.3	SPRAY LUBRICANT TO DRIVE MOTOR CHAIN WITH STRAW NOZZLE.	17.1
2.4	SPRAY LUBRICANT TO TWO RACK/CHASSIS SLIDES WITH STRAW NOZZLE.	18.9
2.5	SPRAY SOLVENT TO CIRCUIT CARD.	9.3
2.6	SPRAY SOLVENT TO FILM PROCESSING UNIT DEVELOPER TANK.	72.0
2.7	SPRAY SOLVENT TO FILM PROCESSING UNIT FILM ROLLER SURFACE.	5.6
2.8	SPRAY SOLVENT TO INTERIOR SURFACE OF EQUIPMENT SIDE PANEL.	9.5
3.0 CLEAN: INTERNAL/EXTERNAL COMPONENTS, AS NEEDED.		
3.1	AIR FILTER (RECTANGULAR FIBER MESH APPROX. 1" DEEP, 3" WIDE, AND 48" LONG) DIPPING FILTER IN SOAPY WATER SOLUTION.	45.0
3.2	AIR FILTER (SMALL MESH STRIP) WITH VACUUM CLEANER THAT HAS A TAPERED NOZZLE.	24.0
3.3	AIR TUBE WITH SOLVENT AND A LINT-FREE CLOTH.	225.0
3.4	ANGLE BAR BRACKET WITH SOLVENT AND A LINT-FREE CLOTH.	90.0
3.5	BAFFLE SEAL WITH SOLVENT AND A LINT-FREE CLOTH.	36.0
3.6	SIX BEARINGS USING SOLVENT AND A LINT-FREE CLOTH.	27.7
3.7	CAM ASSEMBLY USING SOLVENT, WIRE BRUSH, AND ELECTRIC DRILL TO REMOVE DRIED CAKED-ON CHEMICAL RESIDUE.	150.0

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
CLEAN (CONT.):		
3.8	CHASSIS/RACK SLIDES (2) USING SOLVENT AND A LINT-FREE CLOTH.	27.7
3.9	THREE CLIP FASTENERS (U-SHAPED) WITH SOLVENT AND A LINT-FREE CLOTH.	102.9
3.10	DRIVE MOTOR CHAIN WITH SOLVENT AND A LINT-FREE CLOTH.	27.7
3.11	CIRCUIT CARD WITHIN INTERNAL CHASSIS WITH A VACUUM CLEANER THAT HAS A TAPERED NOZZLE.	48.0
3.12	COMPUTER DISK DRIVE AIR MANIFOLD (PLENUM) ASSEMBLY WITH VACUUM CLEANER WITH A TAPERED NOZZLE.	30.0
3.13	COMPUTER DISK DRIVE EXTERIOR WITH A VACUUM CLEANER THAT HAS A TAPERED NOZZLE.	28.2
3.14	COMPUTER DISK DRIVE INTERIOR WITH VACUUM CLEANER THAT HAS A TAPERED NOZZLE.	25.7
3.15	FOUR COMPUTER DISK DRIVE HEADS WITH A SWAB SOAKED IN ISOPROPYL ASCHOHOL.	37.9
3.16	COMPUTER TAPE DRIVE CAPSTAN WITH A DRY LINT-FREE TISSUE.	7.6
3.17	COMPUTER TAPE DRIVE CAPSTAN "PUCK" ASSEMBLY WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT-FREE CLOTH.	5.8
3.18	COMPUTER TAPE DRIVE END OF TAPE/BEGINNING OF TAPE SENSOR WITH A DRY LINT-FREE SWAB.	2.0
3.19	COMPUTER TAPE DRIVE END OF TAPE/BEGINNING OF TAPE SENSORS WITH A VACUUM CLEANER THAT HAS A TAPERED NOZZLE.	3.8
3.20	TWO COMPUTER TAPE DRIVE END OF TAPE/BEGINNING OF TAPE SENSORS WITH AN ISOPROPYL ALCHOHOL-SOKED SWAB.	5.8
3.21	COMPUTER TAPE DRIVE EXTERIOR WITH A VACUUM CLEANER THAT HAS A TAPERED NOZZLE.	28.2
3.22	COMPUTER TAPE DRIVE EXTERNAL SURFACE WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT-FREE CLOTH.	27.9
3.23	COMPUTER TAPE DRIVE GLASS DOOR (BACK) WITH WINDOW CLEANER AND LINT-FREE CLOTH.	9.7

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
CLEAN (CONT.):		
3.24	COMPUTER TAPE DRIVE GLASS DOOR (FRONT) WITH WINDOW CLEANER AND LINT-FREE CLOTH.	9.7
3.25	TWO COMPUTER TAPE DRIVE HALF-MOON TAPE GUIDES WITH AN ISOPROPYL ALCHOHOL-SOAKED SWAB.	5.6
3.26	COMPUTER TAPE DRIVE HEAD ASSEMBLY WITH AN ALCHOHOL-SOAKED COTTON SWAB.	12.7
3.27	FOUR COMPUTER TAPE DRIVE HEADS WITH A SWAB SOAKED IN ISOPROPYL ALCHOHOL.	11.2
3.28	TWO COMPUTER TAPE DRIVE TAPE HEAD GUIDES WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT FREE TISSUE.	17.6
3.29	COMPUTER TAPE DRIVE INTERIOR WITH A VACUUM THAT HAS A TAPERED NOZZLE.	20.7
3.30	COMPUTER TAPE DRIVE INTERNAL VACUUM CHAMBER SURFACE WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT-FREE CLOTH.	9.7
3.31	COMPUTER TAPE DRIVE RACK INTERIOR (BEHIND TAPE TRANSPORT) WITH A VACUUM THAT HAS A TAPERED NOZZLE.	98.5
3.32	EIGHT COMPUTER TAPE DRIVE POST GUIDES WITH AN ISOPROPYL ALCHOHOL-SOAKED SWAB.	22.6
3.33	FOUR COMPUTER TAPE DRIVE ROLLER GUIDES WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT-FREE TISSUE.	22.6
3.34	COMPUTER TAPE DRIVE TAPE CLEANER ASSEMBLY WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT-FREE TISSUE.	18.5
3.35	COMPUTER TAPE DRIVE TAPE PATH WITH A VACUUM CLEANER THAT HAS A TAPERED NOZZLE.	7.7
3.36	COMPUTER TAPE DRIVE VACUUM CHAMBER COVER WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT-FREE CLOTH.	9.6
3.37	FOUR COMPUTER TAPE DRIVE VACUUM CHAMBER ROLLER GUIDES WITH ISOPROPYL ALCHOHOL SOLUTION AND A LINT-FREE CLOTH.	22.8

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
CLEAN (CONT.):		
3.38	TWELVE COMPUTER TAPE DRIVE VACUUM CHAMBER SURFACE AIR-FLOW PORTS USING A VACUUM CLEANER WITH A TAPERED NOZZLE.	25.3
3.39	TWELVE COMPUTER TAPE DRIVE VACUUM CHAMBER SURFACE AIR-FLOW PORTS USING A FINE WIRE (E.G. RESISTOR LEAD) OR SMALL DRILL BIT.	25.7
3.40	CONSOLE EXTERIOR SURFACE (BACK) WITH SPRAY CLEANER AND LINT-FREE CLOTH.	20.0
3.41	CONSOLE EXTERIOR SURFACE (FRONT) WITH SPRAY CLEANER AND LINT-FREE CLOTH.	24.0
3.42	CONSOLE EXTERIOR SURFACE (SIDE) WITH SPRAY CLEANER AND LINT-FREE CLOTH.	30.0
3.43	CONSOLE EXTERIOR SURFACE (TOP) WITH SPRAY CLEANER AND LINT-FREE CLOTH.	17.1
3.44	CONSOLE INTERIOR SECTION USING A VACUUM CLEANER WITH TAPERED NOZZLE.	34.6
3.45	EQUIPMENT CABINET (REAR) INTERIOR BEHIND CABINET DOOR WITH A VACUUM THAT HAS A TAPERED NOZZLE.	51.4
3.46	EQUIPMENT CABINET (FRONT) INTERIOR BEHIND FRONT PANEL WITH A VACUUM THAT HAS A TAPERED NOZZLE.	56.2
3.47	FILM PROCESSING UNIT DEVELOPER PUMP ASSEMBLY WITH SOLVENT AND A LINT-FREE CLOTH.	38.5
3.48	FILM PROCESSING UNIT DEVELOPER TANK SCRUBBING SURFACE WITH SANDPAPER TO REMOVE ANY CAKED-ON DEBRIS.	257.1
3.49	FILM PROCESSING UNIT DEVELOPER TANK COVER (BACK) WITH SOLVENT SPRAY AND LINT-FREE CLOTH (USING SANDPAPER ALSO, IF NECESSARY).	27.7
3.50	FILM PROCESSING UNIT DEVELOPER TANK COVER (FRONT) WITH SOLVENT SPRAY AND LINT-FREE CLOTH (USING SANDPAPER ALSO, IF NECESSARY).	27.7
3.51	FILM PROCESSING UNIT DRIVE SHAFT ASSEMBLY WITH SOLVENT AND A LINT-FREE CLOTH.	180.0

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
CLEAN (CONT.):		
3.52	FILM PROCESSING UNIT FILM GUIDE WITH SOLVENT AND A LINT-FREE CLOTH.	83.1
3.53	FILM PROCESSING UNIT FILM GUIDE SPACER WITH SOLVENT AND A LINT-FREE CLOTH.	22.5
3.54	FILM PROCESSING UNIT FILM ROLLER SCRUBBING WITH SANDPAPER TO REMOVE CAKED-ON DEBRIS.	90.0
3.55	SIX FILM PROCESSING UNIT FILM ROLLER GROOVES WITH A THIN PIECE OF SANDPAPER TO REMOVE CAKED-ON DEBRIS.	205.7
3.56	FILM PROCESSING UNIT INTERIOR SURFACE OF SIDE PLATE SCRUBBING WITH SANDPAPER UNTIL CAKED-ON DEBRIS IS REMOVED.	160.0
3.57	FILM PROCESSING UNIT INTERNAL CHASSIS SURROUNDING DEVELOPER TANK WITH SOLVENT SPRAY AND LINT-FREE CLOTH (USING SANDPAPER ALSO, IF NECESSARY).	27.7
3.58	FILM PROCESSING UNIT RETAINING ROD WITH SOLVENT AND A LINT-FREE CLOTH.	90.0
3.59	FILM PROCESSING UNIT TIE ROD WITH SOLVENT AND A LINT-FREE CLOTH.	90.0
3.60	FILM PROCESSING UNIT TURNAROUND GUIDE WITH SANDPAPER REMOVING ANY ROUGH EDGES.	34.3
3.61	FLAT WASHER WITH SOLVENT AND A LINT-FREE CLOTH, REMOVING CAKED-ON RESIDUE.	22.5
3.62	FRONT PANEL PLASTIC SURFACE WITH SPRAY CLEANER AND A LINT-FREE CLOTH.	32.7
3.63	LOCK WASHER WITH SOLVENT AND A LINT-FREE CLOTH, REMOVING CAKED-ON RESIDUE.	22.5
3.64	NUT WITH SOLVENT AND A LINT-FREE CLOTH, REMOVING CAKED-ON RESIDUE.	22.5
3.65	EIGHT NUTS, FLAT AND LOCK WASHERS WITH SOLVENT AND LINT-FREE CLOTH.	118.3
3.66	1/2" SCREW WITH SOLVENT AND A LINT-FREE CLOTH, REMOVING CAKED-ON RESIDUE.	22.5
3.67	SIGNAL GENERATOR INTERNAL CHASSIS WITH BRUSH, AS NEEDED.	27.7

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
REMOVE (CONT.):		
15.25	CONNECTOR (ROUND, QUARTER-TURN, MULTIPRONGED) FROM BLACK BOX TERMINAL.	3.8
15.26	DRIVE MOTOR CHAIN FROM DRIVE MOTOR UNIT.	19.3
15.27	EQUIPMENT COVER (AFTER ALL SCREWS HAVE BEEN REMOVED).	2.9
15.28	EQUIPMENT COVER PLATE FROM EQUIPMENT.	5.8
15.29	EQUIPMENT SUPPORT BRACKET FROM EQUIPMENT.	7.7
15.30	FILM PROCESSING UNIT CENTER FILM GUIDE (SLIDES OFF OF TIE RODS).	5.6
15.31	FILM PROCESSING UNIT CENTER FILM GUIDE SPACERS (4) (SLIDES OFF OF TIE RODS.)	22.3
15.32	FILM PROCESSING UNIT DEVELOPER PUMP GASKET FROM UNIT.	5.9
15.33	FILM PROCESSING UNIT DEVELOPER PUMP ASSEMBLY.	18.7
15.34	FILM PROCESSING UNIT DRIVE SHAFT (PRESS-FIT) FROM UNIT.	90.0
15.35	FILM PROCESSING UNIT DRYER THERMISTOR ASSEMBLY (ABOUT 8" LONG) FROM UNIT.	55.3
15.36	FILM PROCESSING UNIT FILM GUIDES (7) (SLIDES OFF OF TIE RODS).	36.4
15.37	FILM PROCESSING UNIT FILM GUIDE SPACER FROM FILM ROLLER (SLIDES OFF).	3.9
15.38	FILM PROCESSING UNIT FILM ROLLERS (7) FROM UNIT.	112.5
15.39	FILM PROCESSING UNIT FILM ROLLERS (12) FROM UNIT.	225.0
15.40	FILM PROCESSING UNIT MOTOR/FAN ASSEMBLY FROM EQUIPMENT MOUNTING FRAME.	7.8
15.41	FILM PROCESSING UNIT RETAINING RODS (3) (PRESS-FIT) FROM UNIT.	55.1
15.42	FILM PROCESSING UNIT TIE ROD (PRESS-FIT) FROM UNIT.	18.5
15.43	FRONT PANEL COVER (PULL OFF) AND SET ASIDE.	3.6
15.44	MICROPHONE FROM COCKPIT RECEPTICLE.	1.9
15.45	TWO NUTS, WITH FLAT AND LOCK WASHERS FROM BOLTS.	33.3

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
REMOVE (CONT.):		
15.5	BLACK BOX FROM EQUIPMENT RACK IN REAR OF AIRPLANE.	5.9
15.6	BNC CONNECTOR FROM RECEPTICLE.	1.3
15.7	THREE BNC CONNECTORS FROM RECEPTICLES.	5.8
15.8	CABLE WRAP (APPROX. 5 IN.) FROM A COMPONENT ASSEMBLY.	52.2
15.9	CHASSIS/RACK SLIDE ASSEMBLY FROM UNIT.	2.0
15.10	CIRCUIT CARD ASSEMBLY FROM UNIT.	7.9
15.11	CIRCUIT CARD CONNECTOR FROM CIRCUIT CARD.	7.7
15.12	CIRCUIT CARD COVER FROM CIRCUIT CARD.	7.7
15.13	COMPONENT BACK PANEL WITHIN A CRAMPED CROWDED DIMLY LIT CONSOLE CABINET.	5.6
15.14	COMPUTER DISK FROM DISK DRIVE.	5.5
15.15	COMPUTER DISK COVER FROM DISK.	1.9
15.16	COMPUTER DISK DRIVE AIR MANIFOLD ASSEMBLY.	7.5
15.17	COMPUTER DISK DRIVE SMALL PLASTIC HEAD ASSEMBLY COVER (PULL OFF).	1.9
15.18	COMPUTER TAPE FROM TAPE DRIVE AND SET ASIDE.	5.2
15.19	COMPUTER TAPE FROM TAPE DRIVE PATH.	6.9
15.20	COMPUTER TAPE LEADER MANUALLY FROM TAKE-UP REEL SO THAT ALL OF TAPE IS ON THE SUPPLY REEL.	5.7
15.21	COMPUTER TAPE DRIVE ALIGNMENT GUAGE FROM TAPE DRIVE SUPPLY REEL HUB.	3.8
15.22	COMPUTER TAPE DRIVE CAPSTAN "PUCK" ASSEMBLY.	5.6
15.23	COMPUTER TAPE REEL HOLDER (MULTI-TURN FRICTION LATCH).	8.6
15.24	CONNECTOR (D-SHAPED, MULTIPRONGED) FROM BLACK BOX TERMINAL.	3.8

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
PLACE (CONT.):		
13.70	SIXTEEN 2" SHEET METAL SCREWS WITH FLAT WASHERS INTO SCREW HOLES WITHIN A CRAMPED CROWDED DIMLY LIT CONSOLE CABINET.	52.8
13.71	THREE WING NUTS ON PROTRUDING BOLTS.	13.2
13.72	TWO WIRE LEADS (U-SHAPED) IN SCREW TERMINALS.	9.2
13.73	WIRING WITHIN FOUR CABLE CLAMPS.	92.3
13.74	WIRING COVER (PLASTIC) ONTO LOOSE EXPOSED WIRING.	21.2
14.0 RELEASE: LATCH OR CLIP.		
14.1	CIRCUIT CARD BY PRESSING TWO EJECTOR KEYS ON EACH SIDE OF THE CIRCUIT CARD.	18.0
14.2	FOUR CLIPS (SPRING-LOADED).	21.2
14.3	EIGHT CLIPS (SPRING-LOADED.	42.4
14.4	COMPUTER TAPE HEAD ASSEMBLY LATCH (SLIDES BACK).	2.0
14.5	FRONT PANEL COVER PRESSING TWO RELEASE BUTTONS, ONE ON EACH SIDE OF COVER/PANEL.	3.3
15.0 REMOVE: ITEMS FROM EQUIPMENT.		
15.1	AIR FILTER (SMALL MESH STRIP).	5.7
15.2	AIR FILTER (RECTANGULAR FIBER MESH APPROX. 1" DEEP, 3" WIDE AND 48" LONG (PULL OUT OF INTAKE VENT SLOT).	12.1
15.3	TWO BELTS (ELASTIC) THAT HOLD AN AIR FILTER.	14.1
15.4	TWO BEARINGS (ONE FROM EACH END OF FILM PROCESSING UNIT FILM ROLLER SHAFT).	9.7

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
PLACE (CONT.):		
13.50	LOOSE CABLE INTO PLASTIC WIRING HARNESS.	81.8
13.51	TWO NUTS WITH FLAT AND LOCK WASHERS ONTO TWO BOLTS.	14.8
13.52	EIGHT NUTS, WITH FLAT AND LOCK WASHERS ONTO EIGHT CHASSIS BOLTS.	20.0
13.53	TWO O-RINGS ON FILM ROLLER SHAFT (SLIDE ON).	27.4
13.54	PILOT LINK IN DRIVE MOTOR CHAIN.	35.6
13.55	RACK/CHASSIS SLIDE ASSEMBLY ONTO SIDE OF UNIT.	4.0
13.56	105 ASSORTED SCREWS, NUTS, FLAT AND LOCK WASHERS IN A DISH FILLED WITH SOLVENT.	25.7
13.57	FOUR 1/4" SCREWS WITH FLAT AND LOCK WASHERS INTO SCREW HOLES.	22.3
13.58	TEN 1/4" SCREWS WITH FLAT AND LOCK WASHERS INTO SCREW HOLES.	54.5
13.59	THREE 1/2" MOUNTING SCREWS WITH LOCK AND FLAT WASHERS IN SCREW HOLES.	16.7
13.60	FOUR 1/2" PILLAR BEARING RETAINING SCREWS WITH FLAT AND LOCK WASHERS INTO SCREW HOLES.	22.3
13.61	FOUR 1/2" SCREWS WITH NUTS, FLAT AND LOCK WASHERS INTO SCREW HOLES.	22.3
13.62	FIVE 1/2" SCREWS INTO SCREW HOLES.	24.7
13.63	SIX 1/2" SCREWS, NUTS, FLAT AND LOCK WASHERS IN BRACKET HOLES.	34.4
13.64	FOUR 3/4" SCREWS WITH NUTS, FLAT AND LOCK WASHERS IN SCREW HOLES.	18.8
13.65	TWO 1" SCREWS WITH FLAT AND LOCK WASHERS IN SCREW HOLES.	11.6
13.66	TWO 1" MOUNTING SCREWS WITH NUTS, FLAT AND LOCK WASHERS INTO UNIT BRACKET HOLES.	11.5
13.67	FOUR 1" SCREWS WITH NUTS, FLAT AND LOCK WASHERS INTO SCREW HOLES.	22.5
13.68	THREE 2" SCREWS WITH NUTS, FLAT AND LOCK WASHERS INTO SCREW HOLES.	16.7
13.69	FOUR 2" FLAT-HEAD LOOSE SCREWS WITH BOTH LOCK AND FLAT WASHERS INTO HOLES.	20.0

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
PLACE (CONT.):		
13.31	FILM PROCESSING UNIT BEARING ON THE END OF A FILM ROLLER SHAFT (SLIDES ON).	14.1
13.32	FILM PROCESSING UNIT CAM ASSEMBLY ONTO DRIVE MOTOR SHAFT.	18.0
13.33	FILM PROCESSING UNIT CENTER FILM GUIDE SPACERS (FOUR) ON CENTER FILM ROLLER (SLIDE ON).	22.3
13.34	FILM PROCESSING UNIT DEVELOPER PUMP ASSEMBLY GASKET ONTO UNIT.	13.2
13.35	FILM PROCESSING UNIT DEVELOPER PUMP ASSEMBLY HALVES TOGETHER.	18.5
13.36	FILM PROCESSING UNIT DEVELOPER PUMP ASSEMBLY INTO UNIT.	27.1
13.37	FILM PROCESSING UNIT DRIVE MOTOR CHAIN AROUND DRIVE SHAFT AND CAM ASSEMBLY.	36.9
13.38	FILM PROCESSING UNIT DRIVE ROLLER ASSEMBLY BETWEEN END PLATES (PRESS-FIT).	18.9
13.39	FILM PROCESSING UNIT DRIVE SHAFT ASSEMBLY THROUGH EQUIPMENT END PLATES (PRESS-FIT)	100.8
13.40	FILM PROCESSING UNIT DRYER THERMISTOR ASSEMBLY SLIPPING WIRES THROUGH CABLE WRAP.	79.7
13.41	FILM PROCESSING UNIT END PLATE ONTO TIE ROD.	18.6
13.42	FILM PROCESSING UNIT FILM GUIDE INTO ASSEMBLY.	52.2
13.43	FILM PROCESSING UNIT FILM GUIDES (SEVEN) ON TWO ADJACENT TIE RODS (SLIDES ON).	52.2
13.44	FILM PROCESSING UNIT FILM ROLLER INTO UNIT (PRESS-FIT INTO SPRING-LOADED CLIPS).	60.0
13.45	FILM PROCESSING UNIT FILM ROLLER SPACER ONTO FILM ROLLER SHAFT (SLIDES ON).	5.6
13.46	FILM PROCESSING UNIT LOWER FILM GUIDE (SLIDES ON) MAKING SURE THAT GUIDE IS WITHIN BOTTOM IDLER ROLLER GROOVES.	65.5
13.47	FILM PROCESSING UNIT TUBING (TWO PLASTIC SECTIONS) ONTO DEVELOPER PUMP ASSEMBLY, THROUGH A PAIR OF HOSE CLAMPS.	35.6
13.48	FILM PROCESSING UNIT TURNAROUND GUIDE PLATE ONTO UNIT.	9.5
13.49	FRONT PANEL COVER ONTO FRONT PANEL SO THAT PANEL SNAPS IN PLACE.	9.7

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
PLACE (CONT.):		
13.12	COMPUTER DISK DRIVE AIR FILTER (SMALL MESH STRIP) INTO UNIT.	7.5
13.13	COMPUTER DISK DRIVE AIR MANIFOLD (PLENUM) ASSEMBLY INTO COMPUTER DISK DRIVE UNIT.	7.5
13.14	COMPUTER TAPE IN BULK TAPE DEGAUSSER SLOT.	6.3
13.15	COMPUTER TAPE THROUGH COMPUTER TAPE DRIVE CHANNEL, TO THREAD TAPE.	12.7
13.16	COMPUTER TAPE ONTO TAPE DRIVE HUB.	9.2
13.17	COMPUTER TAPE LEADER INTO COMPUTER TAPE DRIVE TAKE-UP REEL SLOT.	2.0
13.18	COMPUTER TAPE LEADER ON COMPUTER TAPE DRIVE TAKE-UP REEL WINDING TWO REVOLUTIONS BY HAND.	3.5
13.19	COMPUTER TAPE REEL HOLDER (MULTI-TURN FRICTION LATCH) ONTO COMPUTER TAPE DRIVE HUB.	8.6
13.20	COMPUTER TAPE SUPPLY (1/4) ONTO TAKE-UP REEL AFTER SELECTING 'FAST-FORWARD'.	22.5
13.21	COMPUTER TAPE SUPPLY (TOTAL CAPACITY) ONTO TAKE-UP REEL AFTER SELECTING 'FAST-FORWARD'.	55.1
13.22	COMPUTER TAPE AT BOTTOM VACUUM CHAMBER EXIT HOLDING ON TO TAPE WITH HAND.	1.8
13.23	COMPUTER TAPE INTO TAPE DRIVE TAPE PATH.	12.1
13.24	COMPUTER TAPE DRIVE ALLIGNMENT GUAGE ON TAPE DRIVE SUPPLY REEL HUB.	9.0
13.25	COMPUTER TAPE DRIVE CAPSTAN "PUCK" ASSEMBLY BACK ONTO CAPSTAN STEM.	2.0
13.26	COMPUTER TAPE DRIVE VACUUM CHAMBER COVER ONTO UNIT.	8.6
13.27	EQUIPMENT BRACKET BACK INTO UNIT.	18.0
13.28	FILM PROCESSING UNIT AIR TUBES WITHIN UNIT (PRESS-FIT).	144.0
13.29	FILM PROCESSING UNIT ANGLE BARS (TWO) ON END OF TIE ROD.	120.0
13.30	FILM PROCESSING UNIT BAFFLE SEAL TO END OF TIE ROD.	36.0

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
	OPEN (CONT.):	
12.4	COMPUTER TAPE DRIVE HEAD COVER.	1.9
12.5	COMPUTER TAPE DRIVE TAPE DRIVE GLASS MAGNETIC-LATCH DOOR.	1.9
12.6	COMPUTER TAPE DRIVE VACUUM CHAMBER DOOR.	1.9
12.7	FILM PROCESSING UNIT DEVELOPER PUMP ASSEMBLY BY PULLING APART BOTH SIDES.	13.0
13.0	**PLACE:** COMPONENT OR PART ON OR INSIDE OF EQUIPMENT.	
13.1	AIR FILTER (RECTANGULAR FIBER MESH APPROX. 1" DEEP, 3" WIDE AND 48" LONG INTO UNIT (PRESS-FIT INTO INTAKE VENT SLOT).	13.6
13.2	BACK PANEL TO EQUIPMENT WITHIN A CRAMPED CROWDED DIMLY LIT CONSOLE CABINET.	6.9
13.3	TWO BELTS (STRETCHABLE) ONTO AIR FILTER SIDES TO HOLD IN PLACE.	24.0
13.4	BLACK BOX ASSEMBLY IN RACK AT REAR OF AIRPLANE (SLIDES IN).	13.7
13.5	BLOWER UNIT IN EQUIPMENT MOUNTING FRAME.	45.0
13.4	DRIVE MOTOR CHAIN IN A CONTAINER FILLED WITH SOLVENT.	5.9
13.5	CABLE WRAP (APPROX. 5" LENGTH) ONTO WIRING.	60.0
13.6	CHASSIS INTO RACK (ON SLIDES) PUSHING IN AS FAR INTO RACK AS POSSIBLE.	1.9
13.7	CIRCUIT CARD ASSEMBLY INTO UNIT.	15.7
13.8	CIRCUIT CARD COVER (PLASTIC) ONTO CIRCUIT CARD.	13.2
13.9	CIRCUIT CARD INTO CHASSIS SLOT PUSHING CARD IN TO SECURE IT TIGHTLY.	17.1
13.10	COMPUTER DISK IN DISK DRIVE.	5.5
13.11	COMPUTER DISK COVER ONTO DISK.	1.9

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
11.0 MOVE: OBJECT FROM ONE PLACE TO ANOTHER OR A CONTROL THROUGH ITS RANGE.		
11.1	CIRCUIT BOARD/CARD FROM EXTERIOR TEST BANK TO INTERIOR OF EQUIPMENT.	25.0
11.2	CHASSIS BACK AND FORTH ON RACK SLIDES TO VERIFY FREEDOM OF MOVEMENT.	8.6
11.3	COMPUTER DISK DRIVE UNIT PULLING UNIT OUT ON SLIDES AS FAR AS POSSIBLE.	1.9
11.4	COMPUTER DISK DRIVE HEAD COVER SLIDING BACK TO EXPOSE HEADS.	1.9
11.5	COMPUTER DISK DRIVE HEAD COVER SLIDING FORWARD TO COVER HEADS.	1.9
11.6	COMPUTER TAPE HEAD ASSEMBLY TO THE SIDE WITHOUT STRESSING ATTACHED WIRES.	5.2
11.7	DRIVE MOTOR (SLIDES IN BRACKET) SO THAT DRIVE MOTOR CHAIN IS SLACKENED.	5.8
11.8	FRONT PANEL SCREW ADJUSTMENT THROUGH ITS RANGE WHILE OBSERVING AN OSCILLOSCOPE.	4.4
11.9	KNOB (1/2 IN. DIA.) THROUGH ITS RANGE WHILE OBSERVING SCOPE.	3.4
11.10	KNOB (1 1/4 IN. DIA.) THROUGH ITS RANGE WHILE OBSERVING SCOPE.	5.5
11.11	MOUNTING FRAME AWAY FROM CHASSIS WITH CARE. AS FAR AS LENGTH OF WIRE PERMITS.	12.5
11.12	OSCILLOSCOPE PROBE/TEST LEAD FROM TEST POINT TO ANOTHER ON AN EXPOSED CIRCUIT CARD.	5.0
11.13	OSCILLOSCOPE PROBE/TEST LEAD FROM ON TEST POINT TO ANOTHER ON THE EDGE OF AN INTERNAL CIRCUIT CARD WITHIN A CRAMPED CROWDED DIMLY LIT CONSOLE CABINET.	9.1
12.0 OPEN: HINGED DOOR OR CHAMBER.		
12.1	CABINET DOOR (REAR) WITH 1/4 TURN OF A L-SHAPED HANDLE.	4.2
12.2	COMPUTER DISK DRIVE DISK COMPARTMENT DOOR.	1.9
12.3	COMPUTER TAPE DRIVE CASTING.	1.9

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
LOOSEN (CONT.):		
9.13	ONE QUARTER-TURN CAPTIVE SCREW FASTENER.	3.1
9.14	FOUR QUARTER-TURN CAPTIVE SCREW FASTENERS.	9.2
9.15	FOUR QUARTER-TURN THUMB-TURN LATCHES.	10.0
10.0 **MEASURE**: VOLTAGES, WAVEFORM FEATURES, CHECK FOR PROPER DISPLAY.		
10.1	BIAS LEVEL/RIPPLE VOLTAGE ON OSCILLOSCOPE.	5.6
10.2	COMPUTER TAPE DRIVE TAPE ALLIGNMENT COMPARING ORIENTATION OF GUAGE WITH TAPE PATH.	14.1
10.3	COMPUTER TAPE ALLIGNMENT IN TAPE ENTRY AND EXIT CHAMBERS.	1.9
10.4	OSCILLOSCOPE DISPLAY DEVIATION (WAVEFORM OR LINE ON SCREEN).	2.4
10.5	PRESENCE/ABSENCE OF INDICATOR LIGHT AFTER ACTIVATING/DEACTIVATING CONTROL.	4.6
10.6	PRESENCE/ABSENCE OF PROPER FUNCTION AFTER ACTIVATION/DEACTIVATING CONTROL.	7.2
10.7	VISUAL DISPLAY DEVIATION AFTER ACTIVATING/DEACTIVATING CONTROL.	4.1
10.8	VOLTAGE WITH ANALOG VOLTMETER.	2.6
10.9	VOLTAGE ON DIGITAL METER $\pm$ 0.05V.	3.3
10.10	VOLTAGE ON EACH VERTICAL DEFLECTION PLATE OF AN OSCILLOSCOPE.	15.0
10.11	WAVE DISTORTION ON OSCILLOSCOPE AT FREQUENCIES GREATER THAN 600 KHZ.	24.0

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
INSPECT (CONT.):		
8.29	105 ASSORTED SCREWS, NUTS, LOCK AND FLAT WASHERS FOR GOOD CONDITION.	210.0
8.30	SIGNAL GENERATOR INTERIOR FOR LOOSE CONNECTIONS/DEBRIS.	32.1
8.31	TUBING (PLASTIC, TWO SECTIONS) TO VERIFY THAT THERE ARE NO BLOCKAGES OR BUILDUP.	19.0
9.0 LOOSEN: PART SO THAT COMPONENT CAN BE MOVED OR REMOVED.		
9.1	ONE ARINC FASTENER ON EQUIPMENT RACK BRACKET IN REAR OF AIRPLANE.	3.9
9.2	TWO ARINC FASTENERS ON EQUIPMENT RACK BRACKET IN REAR OF AIRPLANE.	7.8
9.3	COMPUTER DISK COVER HANDLE (QUARTER-TURN) TO ALLOW COVER TO BE REMOVED FROM DISK.	1.9
9.4	FOUR HEX-HEAD DRIVE MOTOR ADJUSTMENT BOLTS.	46.7
9.5	TWO HOSE CLAMPS ON TUBING.	27.3
9.6	ONE MULTI-TURN CAPTIVE ALLEN WRENCH SCREW ON COMPUTER TAPE DRIVE CAPSTAN.	16.4
9.7	TWO MULTI-TURN CAPTIVE SCREWS.	18.8
9.8	TWO MULTI-TURN CAPTIVE SCREW TERMINALS SO U-SHAPED WIRING CONNECTORS MAY BE REMOVED.	17.1
9.9	THREE MULTI-TURN CAPTIVE SCREWS.	39.4
9.10	FOUR MULTI-TURN CAPTIVE SCREWS.	10.9
9.11	FOUR MULTI-TURN CAPTIVE SCREWS UNDERNEATH UNIT WITH A SHORT SHAFT SCREWDRIVER, WHICH MUST BE FOUND BY HAND (UNABLE TO SEE SCREWS) IN AN AREA CROWDED WITH CABLES.	152.5
9.12	EIGHT MULTI-TURN CAPTIVE SCREWS.	21.8

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
INSPECT (CONT.):		
8.14	COM/NAV ELECTRICAL SYSTEM CHASSIS IN REAR OF AIRPLANE TO ENSURE THAT PLASTIC TUBING HAS PROPER DRAIN LOOPS AND THAT DRAIN HOLES ARE CLEAR AND UNDAMAGED.	73.5
8.15	COM/NAV ELECTRICAL SYSTEM CHASSIS IN REAR OF AIRPLANE TO ENSURE THAT POTTED CONNECTORS HAVE PROPER ADHESION AND POTTING COUMPOUND IS NOT POROUS OR DETERIORATED.	78.3
8.16	COM/NAV ELECTRICAL SYSTEM CHASSIS IN REAR OF AIRPLANE TO ENSURE THERE IS NO WIRE DETERIORATION, CHAFFING, OR SIGN OF OVERHEATING AND CORROSION.	78.3
8.17	COM/NAV ELECTRICAL SYSTEM CHASSIS IN REAR OF AIRPLANE TO ENSURE THAT WIRE SHIELDS ARE NOT FRAYED AND ARE SECURE.	73.5
8.18	COMPUTER CONSOLE INTERIOR FOR DEBRIS, LOOSE WIRING OR CONNECTIONS, OR ANY ABNORMAL CONDITIONS.	72.0
8.19	COMPUTER TAPE DRIVE CAPSTAN "PUCK" ASSEMBLY FOR PROPER OPERATION AND TIGHTNESS OF FIT.	3.8
8.20	COMPUTER TAPE DRIVE VACUUM CHAMBER FOR ANY LOOSE DEBRIS AND PROPER OPERATION.	3.5
8.21	DRIVE MOTOR CHAIN TO LOCATE PILOT LINK.	28.6
8.22	FILM PROCESSING UNIT DEVELOPER TANK INTERIOR FOR DEBRIS AND/OR CORROSION.	90.0
8.23	FLIM PROCESSING UNIT INTERIOR SURROUNDING DEVELOPER TANK FOR ANY SPLASHED-ON DEBRIS AND/OR ANY CORROSION.	60.0
8.24	FILM PROCESSING UNIT INTERIOR PLATE SURFACE OF EQUIPMENT FOR CAKED-ON DEBRIS.	26.1
8.25	FILM PROCESSING UNIT TURNAROUND GUIDE VISUALLY FOR WEAR.	25.7
8.26	FILM PROCESSING UNIT TURNAROUND GUIDE, FEELING SURFACE EDGES FOR BURRS/ROUGH SPOTS.	25.7
8.27	PART VERIFYING THAT LUBRICATION PORTS ARE ALLIGNED WITH OPENINGS IN ASSEMBLY.	18.0
8.28	SIX RACK SLIDE BEARINGS FOR OVERALL CONDITION AND FREEDOM OF MOVEMENT.	9.2

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
INSPECT (CONT.):		
8.3	AIRCRAFT EQUIPMENT RACKS IN REAR OF AIRPLANE TO ENSURE THAT THEAY ARE SECURE, THAT THERE IS NO CORROSION OR CRACKS, NO LOOSE OR MISSING FASTENERS, AND NO DETERIORATED SHOCK ISOLATION MOUNTS.	146.9
8.4	AIRCRAFT INTERPHONE AND COCKPIT CONTROLES TO ENSURE THAT THERE ARE NO MISSING KNOBS AND THERE ARE NO DENTS, CORROSION, OR DAMAGE TO GUAGES.	78.3
8.5	AIRCRAFT MICROPHONES AND HEADSETS TO ENSURE THAT THERE ARE NO BROKEN CORDS AND THAT ALL CONNECTIONS ARE SECURE.	143.2
8.6	AIRCRAFT RADIO CONTROL UNIT EXTERIOR IN COCKPIT TO ENSURE THAT THERE ARE NO LOOSE OR MISSING KNOBS OR FASTENERS.	82.6
8.7	BLACK BOX EXTERIOR IN REAR OF AIRCRAFT TO ENSURE THAT IT IS SECURE IN THE RACK, CLEAN, THAT THERE ARE NO LOOSE CONNECTORS, NO SIGN OF OVERHEATING, AND NO CHAFED WIRES.	156.5
8.8	BLACK BOX ASSEMBLY TO ENSURE THAT THERE IS NO DAMAGE OR CORROSION, THAT IT IS CLEAN AND SECURE, AND THAT SHOCK ISOLATOR MOUNTS ARE NOT DETERIORATED.	92.3
8.9	CABINET CHASSIS EXPOSED IN REAR OF CABINET, VERIFYING THAT ALL CONNECTIONS ARE SECURE AND THAT WIRING IS IN GOOD CONDITION.	24.0
8.10	CIRCUIT CARD FOR DAMAGE, AND FOR ANY PRESENCE OF DIRT AND DEBRIS.	25.7
8.11	FOUR CIRCUIT CARDS WITHIN CHASSIS FOR CONDITION AND TIGHTNESS OF FIT.	28.6
8.12	COM/NAV ELECTRICAL SYSTEM CHASSIS IN REAR OF AIRPLANE TO ENSURE THAT CONNECTORS ARE NOT CRACKED, LOOSE, OR SHOW SIGNS OF OVERHEATING.	76.7
8.13	COM/NAV ELECTRICAL SYSTEM CHASSIS IN REAR OF AIRPLANE TO ENSURE THAT JUMPERS, GROUNDS, AND TERMINAL STRIP CONNECTIONS ARE NOT CORRODED, DAMAGED, OR LOOSE.	101.1

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
6.0 DEGAUSS: MAGNETIC TAPE/DEVICES.		
6.1	COMPUTER TAPE UTILIZING BULK TAPE DEGAUSSER.	51.4
6.2	TWO COMPUTER TAPE DRIVE HALF-MOON TAPE GUIDES WITH A HANDHELD DEGAUSSING DEVICE.	20.0
6.3	FOUR COMPUTER TAPE DRIVE HEADS WITH A HANDHELD DEGAUSSING DEVICE.	35.3
6.4	EIGHT COMPUTER TAPE DRIVE TAPE GUIDE POSTS WITH A STANDARD DEGAUSSING DEVICE.	39.1
7.0 DRY: EQUIPMENT THAT HAS BEEN CLEANED.		
7.1	AIR FILTER (RECTANGULAR FIBER MESH APPROX. 1" DEEP, 3" WIDE, AND 48" LONG) USING A HAND-HELD BLOW DRYER.	128.6
7.2	CIRCUIT CARD, USING BLOW-DRYER WITH A TAPERED NOZZLE.	13.0
7.3	FILM PROCESSING UNIT DEVELOPER TANK WITH LINT-FREE CLOTH.	65.5
7.4	FILM PROCESSING UNIT FILM ROLLER SURFACE WITH A LINT-FREE CLOTH.	54.8
7.5	FILM PROCESSING UNIT INTERIOR PLATE SURFACE WITH A LINT-FREE CLOTH.	18.2
8.0 INSPECT: EQUIPMENT INTERIOR/EXTERIOR.		
8.1	AIRCRAFT ANTENNA UNDER FUSELAGE TO ENSURE THAT THERE IS NO CRACKED INSULATION, NO CORROSION, AND THAT ANTENNA IS SECURE.	156.5
8.2	AIRCRAFT COAXIAL CABLES LEADING TO ANTENNA TO ENSURE THAT THERE IS NO DETERIORATION AND THAT CONNECTIONS ARE SECURE.	72.0

DESIGN FEATURE TABLE (CONT.)

	ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
4.0	CLOSE: HINGED DOOR OR CHAMBER COVER.		
4.1		COMPUTER DISK DRIVE UNIT COVER (SNAPS IN PLACE).	1.9
4.2		COMPUTER TAPE DRIVE TAPE HEAD COVER (PRESS-FIT).	5.8
4.3		COMPUTER TAPE DRIVE VACUUM CHAMBER DOOR.	1.9
4.4		RACK/CHASSIS DOOR, SECURING DOOR WITH 1/4-TURN OF L-SHAPED HANDLE	4.2
5.0	CONNECT: CABLES/ PROBES TO EQUIPMENT OR TEST POINTS.		
5.1		ADAPTER (3 PRONG/2 PRONG) TO AC POWER CORD MALE CONNECTOR.	10.0
5.2		TWO BANANA TYPE CONNECTORS TO EQUIPMENT RECEPTICLE.	6.5
5.3		BNC CABLE FROM EQUIPMENT OUTLET TO TEST APPARATUS OUTLET (BOTH ENDS).	6.2
5.4		ELEVEN BNC (6) AND BANANA (5) TYPE CONNECTORS TO RECEPTICLES.	35.3
5.5		CIRCUIT CARD CONNECTOR TO CIRCUIT CARD TERMINAL ASSURING TIGHT FIT.	32.7
5.6		"D"-SHAPED CONNECTOR TO BLACK BOX TERMINAL.	3.8
5.7		OSCILLOSCOPE PROBE/TEST LEAD TO JUNCTION OF TWO RESISTORS ON EDGE OF AN INTERNAL CARD.	7.5
5.8		OSCILLOSCOPE PROBE/TEST LEAD TO A TEST POINT ON THE EDGE OF AN INTERNAL CARD.	7.9
5.9		OSCILLOSCOPE PROBE/TEST LEAD TO A TEST POINT ON THE EDGE OF AN INTERNAL CARD WORKING WITHIN ACRAMPED CROWDED DIMLY LIT CONSOLE CABINET.	9.1
5.10		OSCILLOSCOPE PROBES/TEST LEADS TO TWO TEST POINTS ON AN EXPOSED CIRCUIT CARD.	6.9
5.11		POWER CORD TO WALL RECEPTICLE.	1.9
5.12		QUARTER-TURN MULTIPRONGED CIRCULAR CONNECTOR TO BLACK BOX TERMINAL.	3.8

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
REMOVE (CONT.):		
15.46	EIGHT NUTS WITH FLAT AND LOCK WASHERS FROM BOLTS.	82.0
15.47	TWO O-RINGS (ONE FROM EACH END OF FILM PROCESSING UNIT FILM ROLLER SHAFT).	9.7
15.48	OSCILLOSCOPE PROBE FROM A TEST POINT ON THE EDGE OF AN INTERNAL CIRCUIT CARD.	1.9
15.49	PILOT LINK FROM DRIVE MOTOR CHAIN.	28.2
15.50	POWER CORD (THREE-PRONG).	3.0
15.51	FOUR 1/4" SCREWS, FLAT AND LOCK WASHERS.	47.2
15.52	TEN 1/4" SCREWS, WITH FLAT AND LOCK WASHERS	126.3
15.53	FOUR 1/2" PILLAR BEARING RETAINING SCREWS WITH FLAT AND LOCK WASHERS.	43.9
15.54	FOUR 1/2" SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	64.0
15.55	FIVE 1/2" SCREWS.	52.2
15.56	SIX 1/2" SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	69.4
15.57	TWO 3/4" SCREWS WITH FLAT AND LOCK WASHERS.	32.7
15.58	FOUR 3/4" SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	52.7
15.59	TWO 1" MOUNTING SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	28.7
15.60	FOUR 1" MACHINE SCREWS WITH FLAT WASHERS.	22.2
15.61	FOUR 1" SCREWS WITH NUTS, LOCK AND FLAT WASHERS.	100.0
15.62	THREE 2" SCREWS WITH NUTS, LOCK AND FLAT WASHERS.	54.5
15.63	FOUR 2" MACHINE SCREWS.	27.3
15.64	FOUR 2" FLAT-HEAD LOOSE SCREWS WITH BOTH LOCK AND FLAT WASHERS.	60.0
15.65	SIXTEEN 2" SHEET METAL SCREWS AND FLAT WASHERS WITHIN A CRAMPED CROWDED DIMLY LIT CONSOLE CABINET.	266.7

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
REMOVE (CONT.):		
15.66	THREE 3 1/2" MOUNTING SCREWS WITH LOCK AND FLAT WASHERS.	35.7
15.67	TUBING (2 PLASTIC SECTIONS) FROM EQUIPMENT.	18.8
15.68	THREE U-FASTENERS.	16.7
15.69	THREE WING NUTS (MULTI-TURN).	21.8
15.70	WIRING COVER (PLASTIC) FROM UNIT.	5.8
15.71	WIRING (LOOSE) FROM UNIT.	18.0
15.72	WIRING FROM FOUR CABLE CLAMPS.	27.6
15.73	WIRING HARNESS BY CUTTING CABLE TIE.	10.0
15.74	FILM PROCESSING UNIT CAM ASSEMBLY FROM DRIVE MOTOR UNIT.	18.5
15.75	DRIVE MOTOR CHAIN FROM SOLVENT BATH.	2.0
15.76	105 ASSORTED SCREWS, NUTS, LOCK AND FLAT WASHERS FROM SOLVENT BATH.	83.7
16.0 RINSE: EQUIPMENT TO REMOVE DEBRIS/DETERGENT.		
16.1	AIR FILTER (RECTANGULAR PLASTIC MESH APPROX. 1"DEEP, 3" WIDE AND 48" LONG).	42.0
17.0 SET: VARIOUS CONTROLS. TO DESIRED FUNCTION.		
17.1	1/2" DIA. KNOB (DISCRETE-STEP).	1.3
17.2	1/2" DIA. CONTINUOUS-STEP KNOB ON FRONT PANEL FOR A REQUIRED OSCILLOSCOPE DISPLAY.	5.0
17.3	3/4" DIA. CONTINUOUS-STEP KNOB ON FRONT PANEL FOR REQUIRED ANALOG METER DISPLAY.	6.5

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
SET (CONT.):		
17.4	3/4" DIA. INNER CONTINUOUS-STEP COAXIAL KNOB ON FRONT PANEL FOR A REQUIRED OSCILLOSCOPE DISPLAY.	6.2
17.5	3/4" DIA. KNOB (DISCRETE-STEP) FOR REQUIRED OSCILLOSCOPE DISPLAY.	2.2
17.6	3/4" DIA. KNOB (INNER COAXIAL KNOB, CONTINUOUS-STEP) 3/4 OF FULL CLOCKWISE/COUNTERCLOCKWISE.	1.5
17.7	3/4" DIA. KNOB (INNER COAXIAL KNOB, CONTINUOUS-STEP) FULLY CLOCKWISE/COUNTERCLOCKWISE.	1.3
17.8	1" DIA. KNOB (CONTINUOUS-STEP, ATTACHED TO 3" DIA. DIAL).	1.3
17.9	1" DIA. KNOB (DISCRETE-STEP) FULL CLOCKWISE/COUNTERCLOCKWISE.	2.5
17.10	1" DIA. POINTER KNOB (DISCRETE-STEP).	1.6
17.11	1 1/2" DIA. KNOB (OUTER COAXIAL KNOB, DISCRETE STEP).	1.5
17.12	2" DIA. POINTER KNOB (DISCRETE-STEP).	1.3
17.13	POTENTIOMETER SCREW FULLY CLOCKWISE/COUNTERCLOCKWISE.	6.0
17.14	PUSH-BUTTON (LOCKING).	1.3
17.15	PUSH-BUTTON (SPRING-LOADED).	1.9
17.16	FOUR THUMB-WHEELS (DISCRETE STEP) TO PROPER RADIO FREQUENCY/CHANNEL.	3.8
17.17	TOGGLE SWITCH (2-WAY) ON FRONT PANEL.	1.3
17.18	TOGGLE SWITCH (2-WAY) ON REAR PANEL.	2.7
17.19	TOGGLE SWITCH (2-WAY) ON FRONT PANEL.	2.4
17.20	TOGGLE SWITCH (3-WAY) ON FRONT PANEL.	1.3

DESIGN FEATURE TABLE (CONT.)

	ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
18.0	**TEST:** EQUIPMENT VIA VARIOUS TECHNIQUES.		
18.1		DRIVE MOTOR CHAIN DRIVE, BY HAND, TO VERIFY THAT THERE IS NO SLIPPAGE OR CHAIN BINDING.	21.2
18.2		FILM PROCESSING UNIT DRIVE WHEEL TURNING DRIVE SHAFT WORM-WHEEL BY HAND TO VERIFY PROPER OPERATION.	27.7
18.3		RADIO (AIRCRAFT) BY CALLING RADIO SHACK ON MICROPHONE AND LISTENING FOR RESPONSE.	12.8
19.0	**TIGHTEN:** SCREWS/ FASTENERS.		
19.1		ALLEN-WRENCH SCREW (MULTI-TURN) ON TOP OF COMPUTER TAPE DRIVE CAPSTAN.	18.9
19.2		ONE ARINC FASTENER TO SECURE BLACK BOX TO AIRCRAFT EQUIPMENT RACK.	5.8
19.3		TWO ARINC FASTENERS TO SECURE BLACK BOX TO AIRCRAFT EQUIPMENT RACK.	11.4
19.4		FOUR BOLTS (HEX-HEAD).	46.7
19.5		COMPUTER DISK COVER HANDLE 1/4-TURN TO SECURE COVER TO DISK.	1.9
19.6		COMPUTER TAPE HOLDER (MULTI-TURN FRICTION LATCH) TO SECURE COMPUTER TAPE ON TAPE HUB.	5.3
19.7		TWO HOSE CLAMPS ON PLASTIC TUBING.	27.3
19.8		FOUR LATCHES (QUARTER-TURN THUMB-TURNED).	13.0
19.9		TWO NUTS WITH LOCK AND FLAT WASHERS ONTO CHASSIS BOLTS.	11.2
19.10		EIGHT NUTS, WITH FLAT AND LOCK WASHERS ONTO CHASSIS BOLTS.	53.3
19.11		ONE SCREW (QUARTER-TURN CAPTIVE).	4.4
19.12		TWO SCREWS (MULTI-TURN CAPTIVE).	18.8
19.13		THREE SCREWS (MULTI-TURN CAPTIVE).	10.6
19.14		FOUR SCREWS (MULTI-TURN CAPTIVE)	21.8

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
TIGHTEN (CONT.):		
19.15	FOUR SCREWS (MULTI-TURN CAPTIVE) UNDERNEATH UNIT WITH A SHORT SHAFT SCREWDRIVER, WHICH MUST BE FOUND BY HAND (UNABLE TO SEE SCREWS) IN AN AREA CROWDED WITH CABLES.	180.3
19.16	FOUR SCREWS (QUARTER TURN CAPTIVE).	26.5
19.17	EIGHT SCREWS (MULTI-TURN CAPTIVE).	21.8
19.18	EIGHT SCREWS (MULTI-TURN) SO FILM PROCESSING UNIT TIE BARS ARE SECURED.	40.0
19.19	FOUR 1/4" SCREWS WITH LOCK AND FLAT WASHERS.	46.7
19.20	TEN 1/4" SCREWS WITH FLAT AND LOCK WASHERS.	102.1
19.21	THREE 1/2" MOUNTING SCREWS WITH LOCK AND FLAT WASHERS.	35.7
19.22	FOUR 1/2" PILLAR BEARING RETAINING SCREWS WITH FLAT AND LOCK WASHERS.	42.7
19.23	FOUR 1/2" SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	41.7
19.24	FIVE 1/2" SCREWS.	42.0
19.25	SIX 1/2" SCREWS, NUTS, FLAT AND LOCK WASHERS.	75.6
19.26	FOUR 3/4" SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	51.4
19.27	TWO 1" SCREWS WITH FLAT AND LOCK WASHERS (LOOSELY).	20.5
19.28	TWO 1" MOUNTING SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	28.2
19.29	FOUR 1" SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	90.0
19.30	THREE 2" SCREWS WITH NUTS, FLAT AND LOCK WASHERS.	48.0
19.31	FOUR 2" MACHINE SCREWS.	34.3
19.32	FOUR 2" FLAT-HEAD LOOSE SCREWS WITH BOTH LOCK AND FLAT WASHERS.	54.5
19.33	SIXTEEN 2" SHEET METAL SCREWS WITH FLAT WASHERS WITHIN A CRAMPED CROWDED DIMLY LIT CONSOLE CABINET.	266.7

DESIGN FEATURE TABLE (CONT.)

ACTION	DESIGN FEATURE DESCRIPTION	MEAN ESTIMATED TIME (SEC.)
TIGHTEN (CONT.):		
19.34	TWO SCREW TERMINALS TO SECURE U-SHAPED WIRE LEADS.	17.1
19.35	THREE WING-NUTS (MULTI-TURN).	21.2
20.0 TYPE: COMMAND/DATA ON KEYBOARD.		
20.1	COMMAND ON COMPUTER KEYBOARD TERMINAL TO OUTPUT TEST SIGNAL (APPROX. 10 KEY STROKES).	9.0

ACRONYM LIST

A/DF	Action/Design Feature
ADM	Advanced Development Model
BIT(E)	Built-In-Test (Equipment)
CAMS	Consolidated Aircraft Maintenance Squadron
DMSP	Defense Meteorological Satellite Program
EDM	Engineering Development Model
FMEA	Failure Mode Effects Analysis
FSD	Full Scale Development
MRC	Maintenance Requirement Card
PM	Preventive Maintenance
PMEL	Precision Measurement Equipment Laboratory
PMI	Preventive Maintenance Instructions
RCM	Reliability Centered Maintenance
SPMA	Scheduled/Preventive Maintenance Actions
T_{actual}	Time to actually complete PM task
$T_{estimated}$	Time estimated to complete PM task
$T_{expected\ actual}$	Time predicted to actually complete PM task

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